Sky and TELESCOPE

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American Astronomers Report

A New Universal Sundial Design

The Earth's Shadow Size at the March Lunar Eclipse

Northern and Southern Star Charts

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Vol. XIX, No. 8

JUNE, 1960

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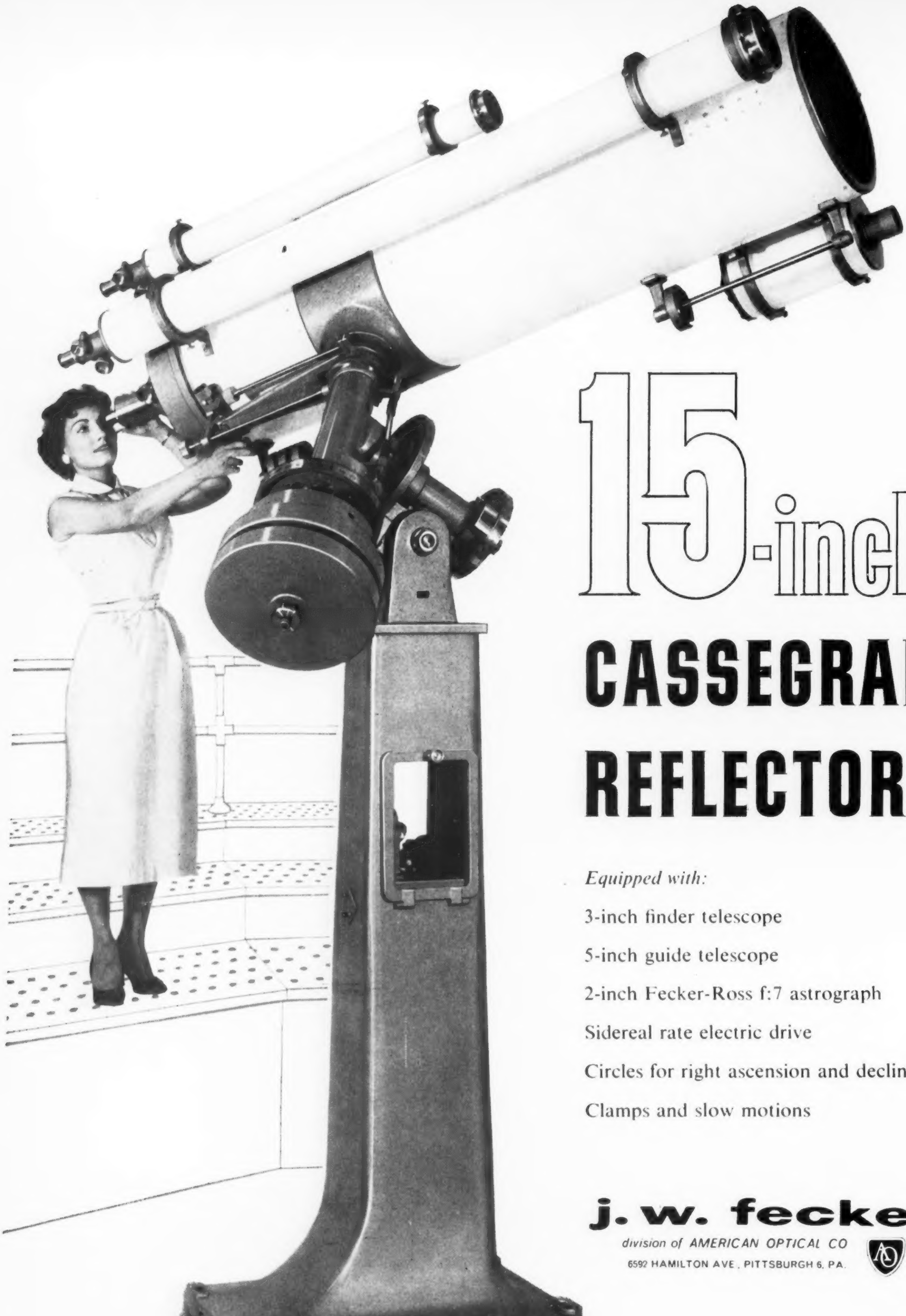


SKY AND TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XIX, No. 8 JUNE, 1960

CONTENTS

FRONT COVER: The giant Thor-Able-Allegany combination rocket that placed satellite Tiros I in orbit on the morning of April 1, 1960, is seen rising from its launching pad at Cape Canaveral, Florida. The new artificial satellite, traveling in a practically circular orbit more than 400 miles above the earth's surface, is televising to ground stations man's first over-all views of the cloud patterns that girdle our planet. National Aeronautics and Space Administration photograph. (See page 459.)

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass. Second-class postage paid at Boston, Mass.

Subscription: $5.00 per year in the United States and possessions; $9.00 for two years; $13.00 for three years. To Canada, Mexico, and all countries of the Pan American Postal Union, $6.00 for one year; $11.00 for two years; $16.00 for three years. To all other foreign countries, $7.00 for one year; $13.00 for two years; $19.00 for three years. Canadian and foreign remittances should be made in United States currency. Single copy 50 cents. Back numbers, as available, 50 cents each.

All notices of change of address must be sent one month in advance and accompanied by old and new addresses. When sending your renewal order, or writing in regard to your subscription, your current mailing address must be given. Return our bill form with renewal payment. Circulation manager, Nancy R. Bolton. Office staff: Virginia K. Cox, J. Caroline Nason, Mary Silva, John Simmons, Helen B. Sniegiecki, Stacia Strong.

Editorial and advertising offices: 49-50-51 Bay State Rd., Cambridge 38, Mass. Advertising rates are listed in STANDARD RATE AND DATA SERVICE, or sent upon request. Advertising manager, Henry M. Corrado. Editorial assistant: William E. Shawcross.

Unsolicited articles and pictures are welcome, bearing adequate return postage, but we cannot guarantee prompt editorial attention, nor are we responsible for the return of unsolicited material. The principal articles are indexed in THE READERS' GUIDE TO PERIODICAL LITERATURE.

The Editors Note . . .

RAPID GROWTH of this magazine in recent years has made it necessary to adopt two volumes per year instead of one, as explained at the foot of this page. As a result of the tremendous rise in popularity of astronomy as a science and a hobby, and because of the growing availability of equipment of all kinds, the past seven years have seen some remarkable changes.

For instance, in 1952 our Here and There with Amateurs listing showed 102 amateur astronomical societies, but the latest (April, 1960) contains 305! During 1951-52 (Vol. XI) each copy of the magazine was 24 or 28 pages, for a yearly total of 316. Vol. XVIII, completed last October, averaged 60 pages an issue, totaling 400 more pages than in 1952. Meanwhile, the number of copies printed each month has more than tripled, now being 34,000.

It was about 1952 that inexpensive imported telescopes of good quality began to reach amateur astronomers in this country. American manufacturers also entered the suddenly active field, producing well-designed reflecting telescopes at moderate cost. Among our advertisers in Vol. XI, there were 38 different manufacturers and publishers, but last year's volume had 89 advertisers.

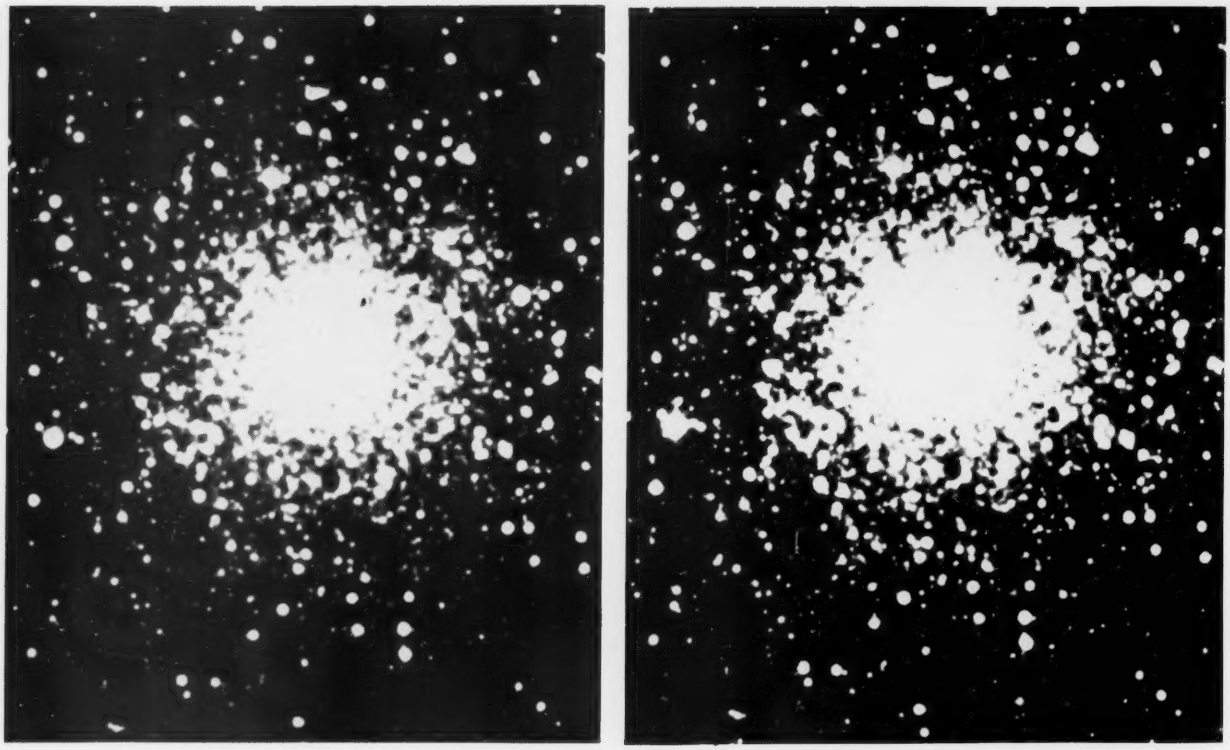
This growth in advertising not only helped newcomers to astronomy in getting started, but enabled us to publish much more astronomical material. We now devote an average of 16½ more pages each month to articles and pictures than we did seven years ago. Amateurs and professionals alike have generously contributed papers and reports, on an ever-widening range of subjects, and to them we are especially indebted.

They have always kept our advance-copy file amply supplied. Happily, our problem each month is to compress into the page allowance as many as possible of the best articles and pictures. Those of most current and lasting interest are selected, but important topics must often be omitted.

ANNOUNCEMENT

Since its beginning in November, 1941, each volume of SKY AND TELESCOPE has contained 12 monthly issues, the volume year ending with the October number. However, this issue terminates Vol. XIX, which began last November and contains eight numbers.

Starting with Vol. XX, July, 1960, SKY AND TELESCOPE will have two volumes a year, one to begin in January and the other in July. The index to Vol. XX will appear in the December issue. New binders for the smaller volume will be available, as announced on page 509.



Although some 40,000 light-years away, the globular NGC 6171 appears a quarter of the moon's diameter. It is shown here in blue light (left) and red light. Around its dense central portion several possible obscured regions are seen, especially an oval blob below center and a four-sided one toward upper right (southeast). Palomar 48-inch Schmidt photographs.

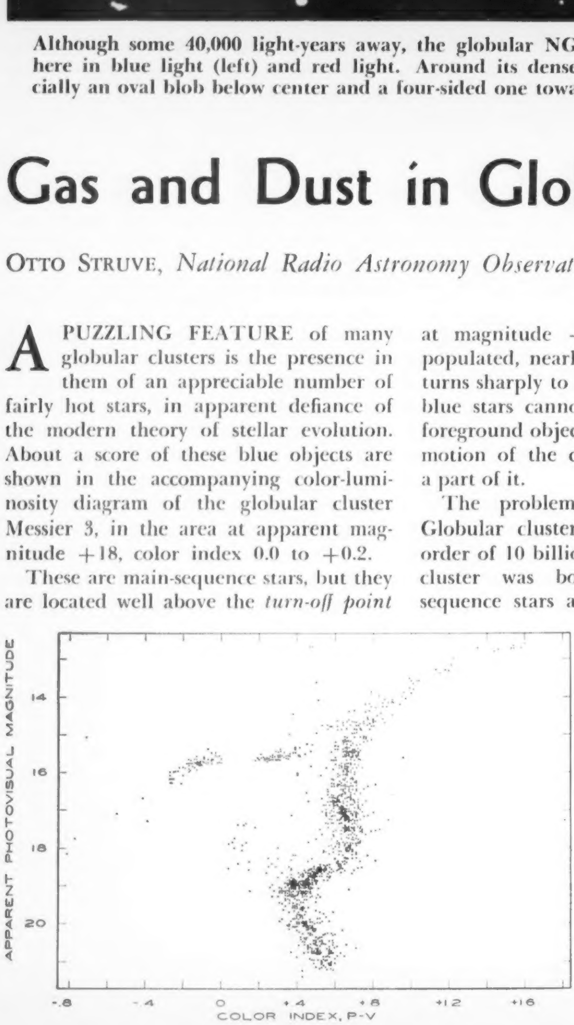
Gas and Dust in Globular Clusters

OTTO STRUVE, *National Radio Astronomy Observatory**

A PUZZLING FEATURE of many globular clusters is the presence in them of an appreciable number of fairly hot stars, in apparent defiance of the modern theory of stellar evolution. About a score of these blue objects are shown in the accompanying color-luminosity diagram of the globular cluster Messier 3, in the area at apparent magnitude +18, color index 0.0 to +0.2.

These are main-sequence stars, but they are located well above the *turn-off point* at magnitude +19, where the densely populated, nearly vertical main sequence turns sharply to the right. These brighter blue stars cannot be explained away as foreground objects, because they share the motion of the cluster and therefore are a part of it.

The problem they present is this. Globular clusters are very old, on the order of 10 billion years. If, when such a cluster was born, there were main-sequence stars above the turn-off point, they must have long since evolved into red giants, which would put them far to the upper right in the diagram. How can we account for their presence now? They are enough like "zero-age" main-sequence stars found elsewhere in the Milky Way galaxy that they cannot be over one billion (10^9) years old, and may in some cases be even younger.



A color-magnitude diagram for stars in the globular cluster Messier 3, by H. C. Arp, W. A. Baum, and A. R. Sandage. Blue stars are toward the left, bright ones toward the top. The main sequence is the densely populated short band near the bottom of the diagram, running from the lower right toward upper left.

The first explanation that might be given is that the process of star formation continues over a very long interval. In the much younger galactic clusters, we have direct evidence that member stars were not all formed at the same time, and there are strong reasons for believing that stars are at present being born in, for example, the Orion nebula. We might conjecture that even though most stars in a globular cluster originated 10 billion years ago, enough interstellar gas and dust remained at much later times to permit the formation of what are now a few relatively young stars.

But this hypothesis is contradicted by our belief that a globular cluster is swept clean of dust and gas when it travels

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

through the central plane of our galaxy. The period of revolution of a typical globular in its highly elongated orbit around the nucleus of the Milky Way is of the order of 100 million years. Hence, each cluster has passed through the Milky Way about a hundred times, and should have lost all of its *original* interstellar material.

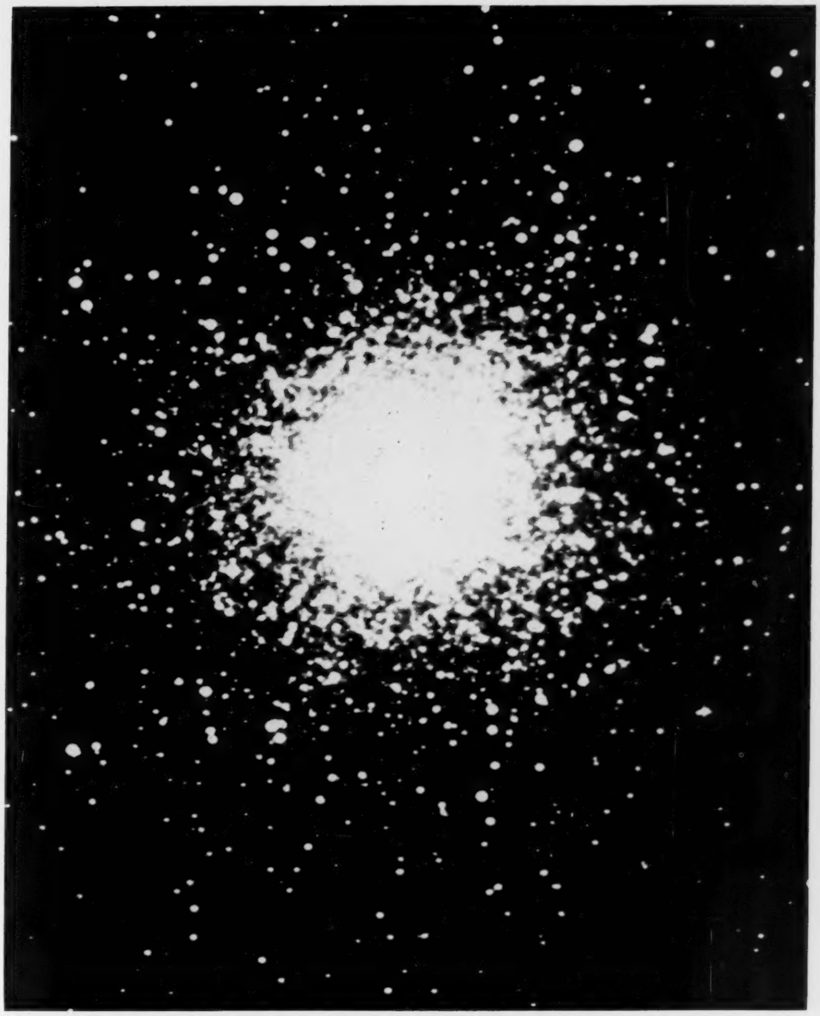
A second way of explaining the present existence of the hot blue main-sequence stars involves an alternative view of their evolution. The change of such stars into red giants has been predicted on the assumption that there is little mixing of the gases in their interiors. If there is efficient mixing, the outer layers would be rapidly transported inward to where they could participate in nuclear reactions at temperatures of about 20 million degrees. Matter from the deep interior would flow outward to where it temporarily ceases to generate energy. Theoretical astrophysicists pointed out many years ago that under these conditions the evolutionary track of a star would run upward, almost along the main sequence, as the total supply of hydrogen fuel decreased.

However, L. Mestel and others have shown that in most ordinary stars mixing is exceedingly slow, and matter from the outermost layers never actually reaches the hot core. Only in rapidly rotating bodies might there be meridional currents of gas, which could speed up the mixing process sufficiently to affect the evolutionary tracks perceptibly. But the difficult mathematical problem of mixing in rotating stars has not been worked out in full detail, and we really do not know whether mixing is ever fast enough for a star to evolve upward along the main sequence.

A third hypothesis assumes that, even though the original gas and dust inside a globular cluster was swept away during its first few passages through the galactic plane, there could be some mechanism continually operating to produce inside the cluster a small amount of diffuse matter. Then a few stars might be able to condense out of this material during the relatively long intervals between the sweepings out. Star formation at a greatly reduced rate might thereby still be going on in all globular clusters.

This proposal immediately raises the question: Has such diffuse matter actually been detected in globulars? A summary of what we know about this was given by Helen Sawyer Hogg at a symposium on globular clusters held at Toronto last year, during the meeting of the American Astronomical Society. She said:

"An important difference, most inadequately investigated, is the obvious streaks of dark nebulosity in certain globular clusters, in high or low latitudes. Among high-latitude clusters, they are very conspicuous in M13, M3, and M2, and less marked in M5 and M15. Whether or not



M13 in red light, taken by A. Mowbray with the 36-inch Lick reflector. On the overexposed central area's southeast (upper-right) edge is an elongated dark lane, ascribed by Morton Roberts to an obscuring intraglobular cloud.

the dark streaks in M13 are the optical result of chance star chains has been a controversial subject for 60 years. Many pages have been written to prove that they are illusions, due to chance groupings of stars, or to show that it is not possible for diffuse nebulosity to exist in a globular cluster.

"As a person who has handled large-scale plates of globular clusters steadily for over thirty years, I stand firmly on the side that the dark lanes in the Hercules cluster and certain others are real patches of nebulosity, and are not effects of random groupings of stars. Whether the nebulosity is actually a part of the cluster, or is a wisp of interstellar material between us and the cluster, I have no conviction. But if there are small wisps of material in high galactic latitudes, can you name any other object against which they would show so well in projection as a globular cluster? Against an external galaxy it would be taken for granted that they were part of it. The time interval of large-scale cluster photographs may even now be getting sufficiently large that relative motion of the dark lanes with respect to the cluster stars, or relative dimming or brightening of cluster stars contiguous to the dark lanes, may be measurable." [From *Astronomical Journal,* December, 1959, page 427.]

As Mrs. Hogg stated, the dark lanes in globular clusters have been known for many years. As early as 1861, Lord Rosse published a sketch of M13, the great Hercules cluster, which shows them. E. S. Holden photographed them in 1890-91 at Lick Observatory. In 1955, A. P. Fitzgerald observed some dark patches in Omega Centauri, and four years later G. M. Idlis and M. Nikolsky commented upon the obscured regions in M4.

There is an interesting discussion of this problem in a yet unpublished paper by Morton S. Roberts, of the Berkeley astronomical department of the University of California. He has examined photographs in the Palomar Observatory sky survey with the 48-inch Schmidt telescope and pictures taken with the 36-inch Cross-

ley reflector at Lick Observatory. He has prepared a list of 12 globular clusters, out of 32 studied, that have one or more dark regions in them. The 32 clusters together cover 0.8 square degree of the sky. Since they contain at least 16 dark patches, the latter occur at the rate of 16/0.8 or 20 per square degree.

According to Roberts, this indicates that the dark lanes are *not* due to foreground wisps of absorption in our galaxy, as these are too few. All of the 32 clusters are at least 15 degrees from the central galactic plane, while even along the Milky Way there seems to be only about one dark globule per square degree, according to B. J. Bok and Edith F. Reilly. Although this argument is reasonably convincing, it is perhaps too early to regard it as more than a good guess.

If Roberts is correct, then the following question arises: Are the dark markings caused by obscuring dust clouds in the clusters, or are they merely statistical fluctuations in the distribution of cluster stars, areas where the stars by chance are few? The latter is highly unlikely, but to make sure Roberts has computed an artificial "model" of a cluster, using for this purpose a table of random numbers.

The number of star-free regions in the model decreases with increasing size of the region, dropping to zero at about 200 square seconds of arc. The most definite dark region in M13, at position angle 130° (upper right) in the page 457 picture, measures about 460 square seconds. The probability of finding such a large area vacant, as a result of statistical fluctuations, is effectively zero.

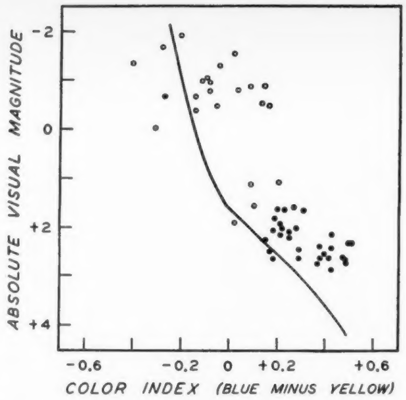
Hence, if the dark regions are really located within the globulars, the obscuration that they reveal must be due to interstellar dust. Roberts assumes for the prominent M13 absorbing lane a cylindrical shape having a volume of about 25 cubic light-years, or some 7×10^{55} cubic centimeters. The absorbing effect of the cloud, at least five magnitudes photographically, implies about 7.5×10^{-23} gram of dust per cubic centimeter. Thus, the dust content of the entire cloud in M13 would be roughly 5.2×10^{33} grams, or about 2.6 solar masses.

In the interstellar clouds of our Milky Way, dust particles account for only about one per cent of the total mass, the rest being gas – mostly hydrogen. Hence, Roberts finds that the M13 dark lane may contain an over-all mass of about 260 suns. He suggests that the total gas and dust in a typical globular cluster having several dark patches might equal 1,000 suns.

Roberts thinks that this diffuse matter in globulars is not the remains of their original dust and gas. Also, it could not have been collected by the clusters from the halo of the galaxy. Instead, he shows that a sufficient amount of gas may be released within the clusters when their fairly massive Population II stars shed material explosively to become white dwarfs (perhaps by supernovae processes).

He refers in particular to computations made in 1957 by H. Takebe and N. Matsunami, and by A. R. Sandage. The latter's results for M3 indicated that the *total* amount of ejected material could be half the present mass of the cluster, or about 100,000 suns. If, during its past lifetime, the cluster has made 100 revolutions around the galactic center, then approximately 1,000 solar masses could accumulate in the system before being swept out.

The Berkeley astronomer gives some reasons for believing that the time would be long enough for fresh stars to evolve from the diffuse matter before it was lost.



Blue stars of nine globular clusters are plotted in this composite color-magnitude diagram. Black dots indicate stars in Messier 3, while the curve shows the course of the zero-age main sequence. This chart is courtesy of Morton S. Roberts.

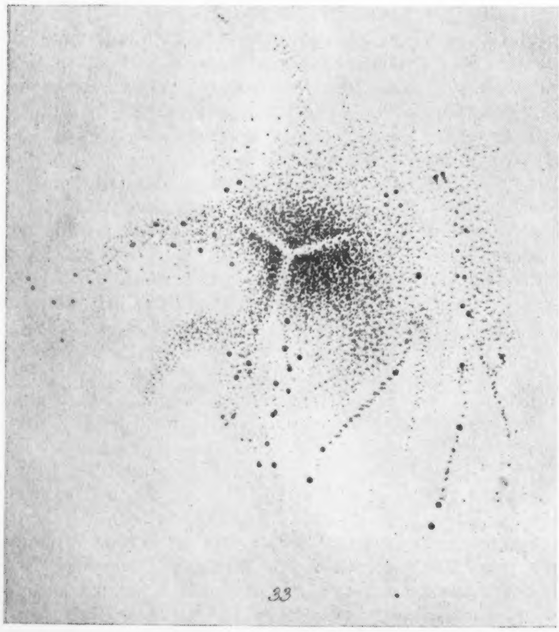
Presumably a protostar or globule could condense quite rapidly, and would not necessarily have to become a main-sequence object in order to be safe from the consequences of crossing through the plane of the Milky Way. In such a passage, stars and dense knots of matter would be relatively undisturbed, in comparison to more extended clouds.

Because the obscured regions in certain globulars appear to be fairly distinct clouds, the young stars that form within the cloud should be in groups, not distributed with spherical symmetry as are the old stars of Population II. For M3, Roberts finds that the blue stars do, in fact, tend to appear together in groups, but for other globulars the data are too scanty for any conclusions to be drawn.

Thus far, the only observational evidence for the existence of diffuse matter in globular clusters comes from the apparent obscuration by dust. No nebulosities with emission spectra have been discovered in globulars, except for one planetary nebula inside M15. This single exception is, perhaps, consistent with the rarity of planetaries in the Milky Way; furthermore, it lends some support to the hypothesis that old stars in globulars are expelling gas.

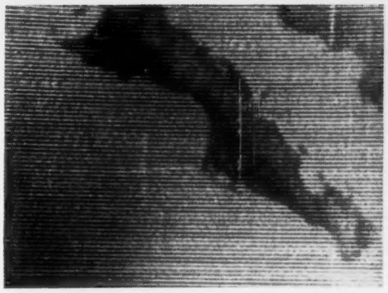
Roberts has calculated that the ionization of hydrogen in the diffuse clouds within clusters will not produce Balmer emission lines strong enough to be detected on spectrograms. Neither has he found the 21-centimeter line of hydrogen to be observable in M3 and M13 with the 85-foot radio telescope of the National Radio Astronomy Observatory.

One unanswered question is why the diffuse material that is shed by Population II stars should collect in compact, very dense nebulosities. Gas expulsion would be expected throughout the cluster, and the gas should therefore be distributed with a spherical symmetry, like the old stars themselves.



Dark lanes in M13 are shown in this drawing of May, 1851, made with Lord Rosse's 72-inch reflector at Birr Castle. The Irish amateur first recorded these features on May 6, 1850, and on the following April 6th commented that these streaks bore some resemblance to the dark lanes in the great Andromeda nebula. From "Philosophical Transactions" of the Royal Society (1861).

OBSERVING THE SATELLITES



Part of Lower California and a bit of mainland Mexico, as viewed by Tiros' wide-angle TV camera. The image was tape recorded, then radioed to Hawaii.

Earth Observations from an Artificial Satellite

THE FEASIBILITY of surveying cloud patterns on a global scale has been demonstrated by the television system of Tiros I. This experimental weather-reconnaissance satellite was launched from Cape Canaveral on April 1st at 11:40:09 Universal time, under the auspices of the National Aeronautics and Space Administration (see front-cover picture).

The name *Tiros* is coined from *T*elevision and *I*nfrared *O*bservation *S*atellite, foreshadowing the use in future experiments of infrared detectors, in order to map the surface temperature of the earth. These heat sensors were not ready in time for the April ascent, but the television system has already revealed cloud systems encompassing unexpectedly large portions of the earth.

A Thor-Able-Allegany Ballistics Laboratory rocket configuration, similar to the one that placed Pioneer V in orbit around the sun on March 11th, was used to attain a nearly circular terrestrial orbit. The spin-stabilized 500-pound third stage, with the 270-pound payload attached, coasted upward for 6½ minutes after second-stage separation before it fired.

During this interval the vehicle was tracked by the Millstone Hill radar installation, at Westford, Massachusetts. Longer-range tracking was made possible by a newly developed repeater beacon attached to the third-stage rocket, thus permitting more accurate orbit determination.

The intended trajectory was achieved with high precision. At its burnout, the third stage was traveling 24,654 feet per second, within 0.1 per cent of the desired figure. The orbital inclination was determined as 48.4 degrees, very close to that planned. For observations of clouds, a circular orbit was intended, and the actual initial eccentricity amounted to only 0.0045.

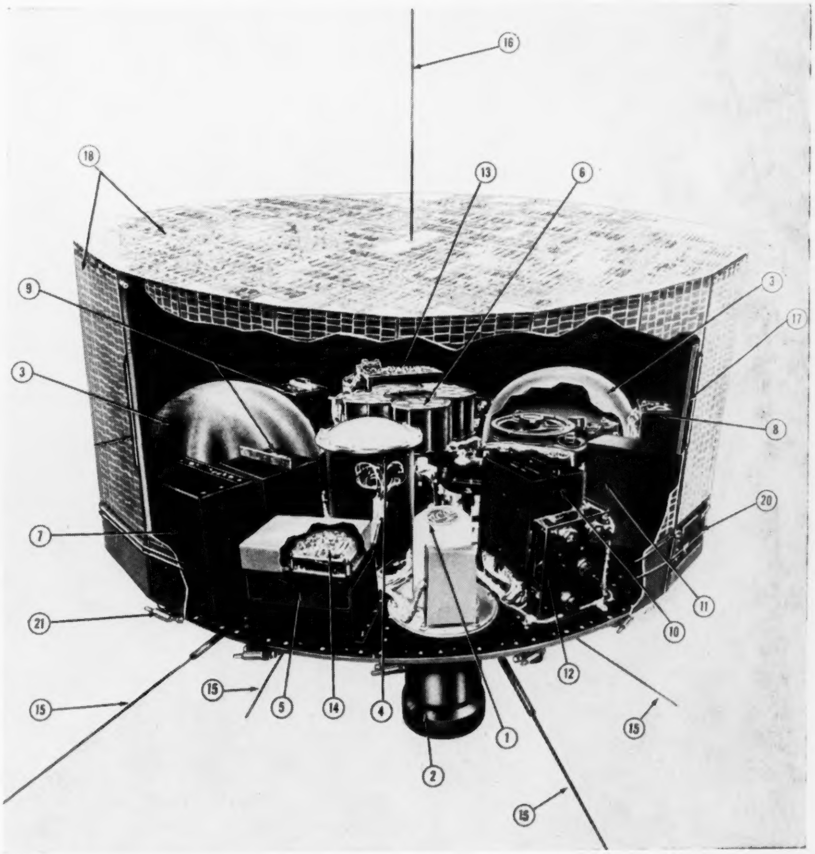
Tiros is shaped like a giant hatbox, about 42 inches in diameter and 19 inches high, its top and sides covered with 9,000 solar cells. When this payload was injected into orbit, it was traveling slightly north of eastward, off the coast of Nova Scotia, with the six-foot-long final rocket case attached behind it.

Some 25 minutes later, when the satellite had completed about one-fourth of a revolution, it was passing southeastward over the Arabian Desert, north of Yemen. At this point, the rocket case was nearly below the satellite, since their relative orientation in space was unaffected by the motion in orbit. Powerful springs then forced the empty 50-pound rocket casing away from the instrument package.

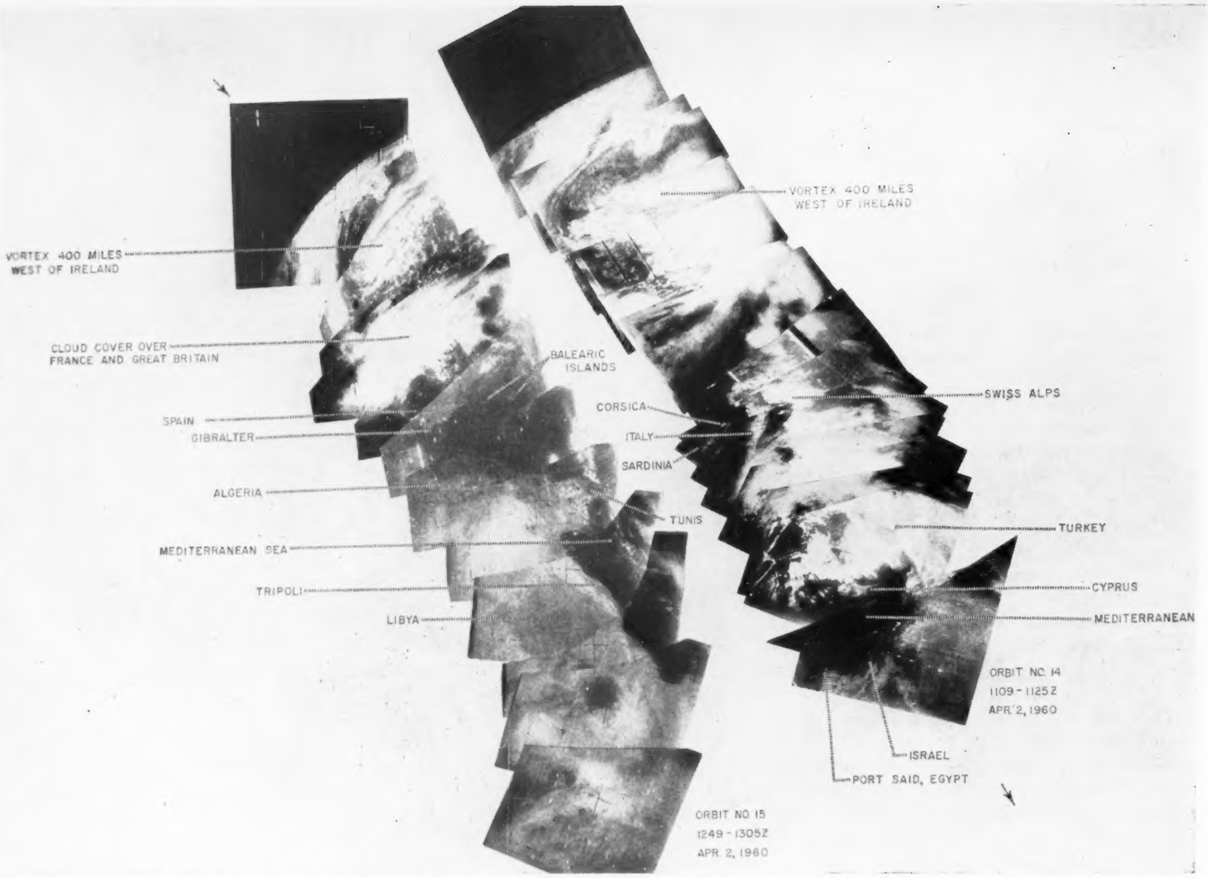
At the same time, the payload was spinning around a nearly vertical axis at about 136 revolutions per minute – too fast for unblurred television operation. To brake the rotation, about 10 minutes after the separation two weights attached to long cables were released. As these swung outward, the spin slowed to some 12 times a minute, and then the cables slipped off their hooks and away from the payload, as planned. Soon afterward, weights within the satellite were released to shift along rods, serving as precession dampers.

In order to counteract the gradual slowing of rotation caused by interaction with the earth's magnetic field, three pairs of small spin rockets around the lower rim of the hatbox can be fired on ground command, when the spin becomes slower than nine revolutions per minute. At the time of writing (May 1st) none of these pairs had been fired.

To exploit scientifically the televised views of the earth, it is necessary to know for each moment the directions of the sun and horizon, as seen from the satellite. Two sets of sensors were provided for this, small infrared detectors being used to locate the horizon. The need for this elaborate system was demonstrated by the difficulties in interpreting cloud data from Vanguard II, whose spin was employed to scan the earth. Even for Tiros, there

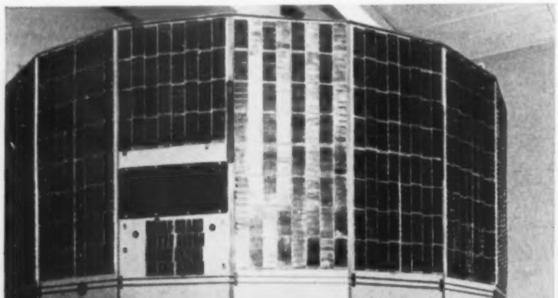


This cutaway drawing shows payload details of the meteorological satellite Tiros, launched on April 1, 1960. Labeled here are: 1, one of the two Vidicon TV cameras; 2, wide-angle camera lens; 3, tape recorders; 4, electronic timer for operations sequence; 5, TV transmitter; 6, chemical batteries; 7, camera electronics; 8, tape-recorder electronics; 9, control circuits; 10, auxiliary controls; 11, power converter for tape motor; 12, voltage regulator; 13, battery-charging regulator; 14, auxiliary synchronizing generator for TV; 15, transmitting antennas; 16, receiving antenna; 17, solar sensor; 18, solar cells; 20, de-spin mechanism; and 21, spin rockets (only three pairs were actually fitted). Both illustrations here are from National Aeronautics and Space Administration.



These two mosaics consist of 30 photographs by Tiros during its 14th and 15th circuits of the globe, on April 2nd. They show a vast cloud pattern associated with a mature cyclonic vortex about 400 miles west of Ireland. Cloud cover extends from Great Britain to Turkey, but skies were clear from the Strait of Gibraltar to Israel. Weather Bureau-NASA photo.

are some minor malfunctionings; the horizon sensors seem too responsive to small changes, and give data too complex for interpretation by the original electronic computer program. Also, there is some residual wobble, of a period too long to be controlled by the precession dampers. Together, these effects complicate the analysis of the cloud pictures.



The Tiros payload being given a vibration test at the Astro-Electronic Products Division of RCA, at Princeton, New Jersey. This satellite was designed and constructed by RCA, under the technical supervision of the U. S. Army Signal Research and Development Laboratory, Ft. Monmouth, New Jersey. Covering the sides of the cylindrical body can be seen some of the 9,000 solar cells that furnish electrical power. On May 1st this payload had a perigee height of 433.6 miles and an apogee of 473.3. The rocket casing had the same perigee, but apogee was 472.5. NASA photograph.

The television system in Tiros is powered by nickel-cadmium batteries that are kept charged by the solar cells. In all, the power consumption is about 19 watts. There are two television cameras having identical ½-inch Vidicon tubes, both with focal-plane shutters that provide 0.0015-second exposures. The cameras differ only in their lenses, one being an f/1.5 of about ¼-inch focus. This has a wide field of view, about 800 miles on a side from a height of 400 miles. The other is an f/1.8 2½-inch lens, covering an 80-mile square.

Images stored on the photoconductors of the Vidicon tubes are electronically scanned and converted into video signals. Some 250 picture elements form each line, and there are 500 lines per frame. The frame is scanned in two seconds, at a video band-width of 62.5 kilocycles per second. Magnetic tape traveling 50 inches per second can be used for storing the relatively slow video signal. Each camera has its own tape recorder with 400 feet of Mylar-base magnetic tape, enough for at least 32 consecutive frames.

When operated in this manner, the cameras take two exposures per minute, beginning at pre-selected times, which are stored in the satellite's memory device

by ground command. During readout of the tapes, in response to a radio order from a ground station, the 62.5-kilocycle signals modulate a 235-megacycle FM transmitter, operating at two watts. At two receiving stations — Ft. Monmouth, New Jersey, and Kaena Point, Hawaii — the transmitted pictures are displayed on a television system and photographed.

Alternatively, the cameras can transmit directly through the FM carrier, if desired, by-passing the tape-recorder system. This way of operation is feasible only when the satellite is above the horizon of a ground station. This was a fortunate provision, since the timer that regulated the tape recorder for the telephoto camera broke down soon after Tiros was put in orbit.

The problem of obtaining the maximum amount of televised information is complicated by the changing relations of the satellite's orbit plane, spin axis, and the sunrise-sunset line on earth. But the spin axis' departure from its intended orientation actually improves performance in some ways. Originally, views of the Northern Hemisphere were expected during the first 20 days in orbit, then those of the earth's southern portions until about the 35th day, then the Northern Hemisphere again until the 90th. Many of these views would be toward a very distant horizon, but a fair proportion would be nearly vertical.

Tiros has already yielded some highly significant scientific results. Weather Bureau meteorologists have found an unanticipated degree of large-scale organization in cloud systems. Previously, ground observations had covered only about one-fifth of the earth with reasonable completeness. The cost of a continuous patrol of the remaining areas should be less for satellites than for ships or planes.

A second Tiros is scheduled for late-summer launching by a Thor-Delta vehicle. It will be followed by a series of Nimbus meteorological satellites, featuring

This Tiros-eye view shows the Strait of Gibraltar, with clouds covering much of Spain and Portugal, while Morocco is clear. NASA photograph.

improved sensors that are to control orientation in polar orbits. The first Nimbus will be sent aloft, perhaps in late 1961, by a Thor-Agena B combination.

The third-stage rocket case of Tiros is larger and brighter than the instrument package itself, and hence they are designated 1960β1 and 1960β2, respectively. Their orbits are very similar, the period of revolution of the latter being 99.24 minutes on May 1st, only about 0.01 longer than the third stage's period.

Navigation Satellite

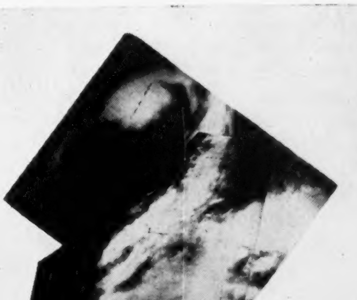
An IMPORTANT new system of sea and air navigation has been brought much nearer practical use by the experimental Transit I-B satellite launched on April 13th. The day may not be far distant when ships at sea will routinely check their positions with the aid of earth-circling radio beacons — an all-weather method unaffected by clouds or by ionospheric disturbances that affect Loran, the present ground-based beacon system.

The 36-inch spherical payload, weighing 265 pounds, was sent aloft from Cape Canaveral at 12:02:36 Universal time that morning. The launching was the responsibility of the Air Force's Ballistic Missile Division, with the help of Space Technology Laboratories. A modified Thor IRBM served as the first stage, and the newly developed Able-Star for the second. The latter incorporated a revolutionary feature — its engine may be shut off after a period of powered flight, then turned on again by command.

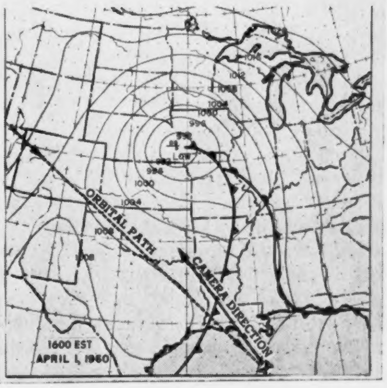
It was planned to give Transit I-B a circular orbit by allowing the second stage to coast up to the desired height of over 500 miles, then restarting its engine to provide the final kick that would attain the circular velocity. As programmed, the second stage fired for 4.3 minutes before coasting upward for 19 minutes, its orientation being controlled by eight jets of nitrogen gas. The second burning period was 13 seconds, after which a pneumatic system started the satellite spinning about 168 times per minute. Seventeen seconds later, explosive charges separated the payload from the Able-Star stage.

The satellite itself is designated 1960γ2, while the second stage (14 feet 10 inches long and 4 feet 7 inches in diameter) that accompanies it in orbit is 1960γ1. Also in orbit is a third object, 1960γ3, detected by radar. This has been tentatively identified as the spin table to which the payload had been fastened.

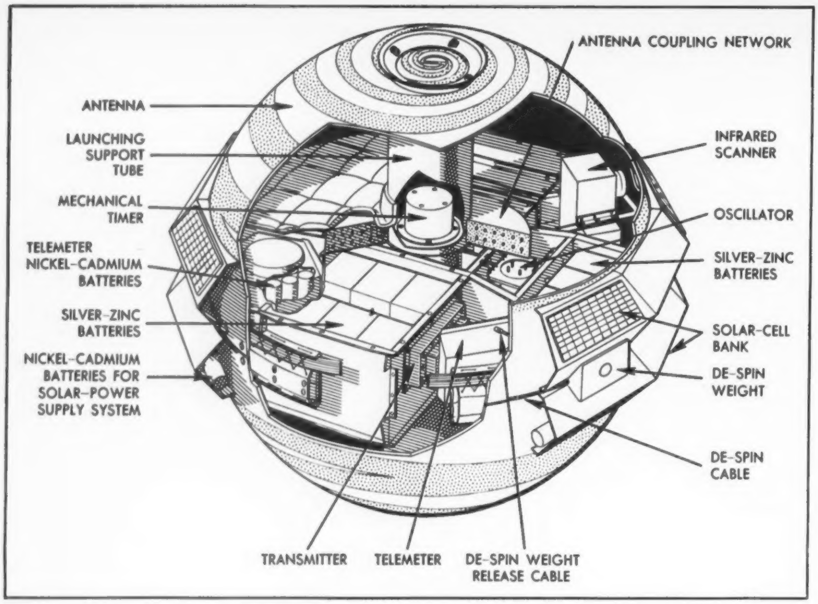
The initial periods of these three bodies



Left: Cloud details observed with the narrow-angle TV camera from 450 miles above the Atlantic seaboard of the United States. Such high-resolution pictures have about 10 times the detail obtainable with the wide-angle camera. NASA photograph.



Right: At the top of the Tiros mosaic is a well-developed storm, centered over Nebraska at 3:30 p.m. EST April 1st. Compare it with the surface weather map (below); the cross marks the place from which the pictures were taken. U. S. Weather Bureau - NASA photographs.



Some components of the 36-inch spherical Transit I-B are labeled here. Most of them are on an equatorial shelf, to aid the satellite's balance. Diagram from Applied Physics Laboratory, Johns Hopkins University.

were 95.9, 95.3, and 94.6 minutes, respectively, and all had orbital inclinations close to 51.3 degrees. Payload and second stage had perigee heights of 239 and 230 miles, respectively, while at apogee they rose to 472 miles. The scanty data for $1960\gamma 3$ gave 447 and 190 miles as its approximate limits.

Among the most important components of the payload sphere are two very stable oscillators, housed in Dewar flasks. These are being used to determine how ionospheric refraction of radio waves influences Doppler-effect measurements. One oscillator controls transmissions at 216 and 162 megacycles per second, and is powered by a double band of solar cells extending around the spherical satellite. The other, for 324- and 54-megacycle transmissions, is served by silver-zinc chemical batteries. Using four frequencies in a single payload gives much detailed information about ionospheric refraction.

Each transmitter operates at one-minute intervals. The antenna for all of them is a silver band painted around the surface of each hemisphere of the fiberglass housing, in the form of a logarithmic spiral. This arrangement permits the antenna to handle the sixfold range of transmitter frequencies.

Five ground tracking stations, in the United States, Canada, and England, are reporting their results to the Applied Physics Laboratory of Johns Hopkins University, which serves as prime contractor for the development of the navigation payload for the U. S. Navy's Bureau of Ordnance.

A second, entirely distinct experiment is also carried aboard Transit I-B, for the measurement of the earth's albedo (reflecting power) for infrared radiation. These results were telemetered to ground at a frequency of 108.03 megacycles until April 16th, when the Minitrack transmitter failed.

As mentioned, initially the Transit satellite was rotating 168 times a minute. By prearrangement, on April 19th two weights on long cables were released, slowing the spin to four times a minute.

Two additional experimental Transit satellites are planned before the actual navigational beacons are put into orbit. As presently envisioned, the complete navigation system will require four satellites simultaneously in orbit, to insure a convenient world-wide coverage. A key feature of the plan is that orbital data will be transmitted to each satellite, so that its continually repeated broadcasts will provide the shipborne navigator with all necessary information for determining his geographical position.

The ship's receiving equipment would include an oscillator for finding the frequency change (Doppler effect) in the received signals. From the manner in which the Doppler shift varies with time, the distance between the ship and satellite can be ascertained. At the moment when the shift becomes zero, the distance is a minimum, and the direction is perpendicular to the satellite's trajectory (to a very close approximation).

In actual practice, allowance will have to be made for the refraction of radio waves in the earth's atmosphere. A suitable shipboard computer should allow geographical positions to be determined with an accuracy of perhaps 0.1 mile.

The Transit navigational system may actually be less expensive to maintain than the Loran now in use, which moreover does not give complete coverage of the globe. Launching each of the operational Transit satellites, for which a five-year lifetime may be anticipated, might cost a million dollars, and the operating expenses of the ground installations could amount to three million dollars a year. Estimates of the cost of the shipborne equipment are comparable to that of Loran devices.

Discoverer XI

THE SEVENTH Discoverer satellite to attain an orbit around the earth is noteworthy as the first probe to carry its own light source. This object was Discoverer XI, sent aloft from Vandenberg Air Force Base in California, on April 15th at 20:30:37 Universal time.

Included in the 300-pound payload of 1960δ was a 10-pound package of tracking devices, which contained a Doppler radio beacon and external lights. The latter were arranged to shine for a few minutes when the satellite passed near each of four Smithsonian stations equipped with Baker-Nunn cameras. These stations, together with certain neighboring Moonwatch groups, were alerted to observe the high-flying speck of light, expected to be of about magnitude 8, as Discoverer XI passed within the shadow of the earth. Three of the four Smithsonian tracking stations were clouded out, but at San Fernando, Spain, successful observations were made.

On the satellite's 17th circuit of the earth, the recovery capsule separated from the Agena, according to telemetry data. But some unknown mishap seems to have occurred shortly after, for the capsule was not observed to descend within the recovery area. It did not continue in the same orbit as the satellite, for radar stations failed to detect it.

According to Space Track, the initial period of 1960δ was 92.3 minutes, and its apogee and perigee heights were about 345 and 110 miles, respectively. The nearly polar orbit had an inclination of about 80.1 degrees. This short-lived satellite is already down, having perished during its 172nd revolution, on April 26th between 17 and 18 hours Universal time. The descent probably took place in the Southern Hemisphere.

Discoverers IX and X had also been fitted with tracking lights, but neither went into orbit. The first failed to attain the necessary velocity; the other was blown up by the range safety officer 56 seconds after take-off.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

CORRECTION

In the first paragraph on page 409 of the May issue, line 9, read "Lunik I" instead of "Lunik III." This error was pointed out by Jay H. Respler, Bronx, New York.

ASTRONOMICAL SCRAPBOOK

William Herschel and the Sun

FEW major astronomical discoveries have remained barren for so many years before springing into life as did the detection of sunspots in 1610 by Galileo and Fabricius. For two centuries following, these temporary dark markings attracted only casual attention, though from many astronomers.

The spots seemed of astronomical importance only in finding the rotation period of the sun, and the direction of its axis. To most astronomers of the 18th century, the sun was merely a convenient skymark for the determination of time and geographical latitude.

The beginnings of solar physics can be traced to Sir William Herschel. In his famous experiment of 1800, the great English astronomer used a prism to spread sunlight into a spectrum, then measured the rise in temperature of a sensitive thermometer exposed to different portions of the colored band. To his surprise, a marked heating effect occurred beyond the red end of the visible spectrum. Often this is nowadays referred to as the discovery of infrared radiation; Herschel, however, concluded that the visible light and the heat of the sun must be essentially different in nature. This misinterpretation of an ingenious experiment misled physicists for a generation, thanks to the prestige of Herschel's name.

In 1796, at a time when he was thinking much about variable stars, Herschel suggested that the sun itself might vary, and that this might explain climatic changes. Looking for some index number to characterize solar radiation, he proposed using the price of wheat in different years. A modern social scientist might call Herschel's notions of economics oversimplified, but clearly here is a pioneer attempt to study solar-terrestrial relations in a modern spirit.

Both these papers of Herschel's were anticipations of things to come, inspirations that awaited physical knowledge in one case, and statistical data in the other, before they bore fruit. The same cannot be said of Herschel's memoir of 1795 on the constitution of the sun, which is a curious survival of older fancies.

From time to time, Herschel noted that the umbrae of sunspots appeared to lie at a lower level than the solar photosphere. For example, "In the year 1783, I observed a fine large spot, and followed it up to the edge of the sun's limb. Here I took notice that the spot was plainly depressed below the surface of the sun; and that it had very broad shelving sides." From a number of such observations, he came to the belief that the sun is encased by a "shining atmosphere," in which occasional gaps occur, revealing the cool, dark "real body of the sun itself."

Analogies were collected to support this idea. To an observer on the moon, the earth's surface would be seen only between cloud areas, and this cover would be in part luminous, because of aurorae. Herschel continued: "Nay, we have pretty good reason to believe, that probably all the planets emit light in some degree; for the illumination that remains on the moon in a total eclipse cannot be entirely ascribed to the light which may reach it by the refraction of the earth's atmosphere. . . . The unenlightened part of the planet Venus has also been seen by different persons . . . this faint illumination must denote some phosphoric quality of the atmosphere of Venus."

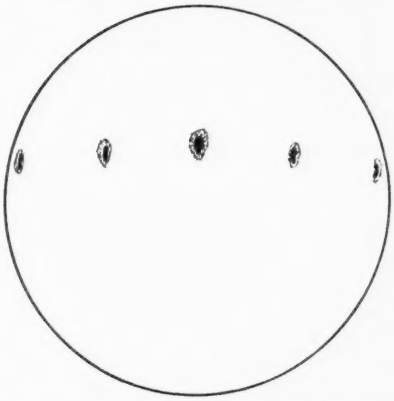
Herschel did not hesitate to carry his speculation further: "The sun, viewed in this light, appears to be nothing else than a very eminent, large, and lucid planet . . . all the others being truly secondary to it. Its similarity to the other globes of the solar system with regard to its solidity, its atmosphere, and its diversified surface; the rotation upon its axis, and the fall of heavy bodies, leads us on to suppose that it is most probably also inhabited, like the rest of the planets, by beings whose organs are adapted to the peculiar circumstances of that vast globe. . . . [I] am persuaded that the foregoing observations, with the conclusions I have drawn from them, are fully sufficient to answer every objection that may be made against it."

Solar inhabitants! This fantasy was actually published in the *Philosophical Transactions* of the Royal Society. The suggestion that the sun was a cool, planetary body with a glowing atmosphere was not new, as John Flamsteed in 1681 and J. E. Bode in 1772 had proposed similar ideas.

But in an English courtroom in 1787, only eight years before Herschel wrote, the holding of this theory was alleged as a proof of insanity. This was the trial of Dr. Elliot for a murderous assault on Miss Boydell. A friend of the accused man offered as evidence of mental derangement a letter Dr. Elliot had written him the year before. This stated "that the sun is not a body of fire, as hath been hitherto supposed, but that its light proceeds from a dense and universal aurora, which may afford ample light to the inhabitants of the surface beneath, and yet be at such a distance aloft as not to annoy them. . . . Vegetation may obtain there as well as with us. There may be water and dry land, hills and dales, rain and fair weather; and as the light, so the season must be eternal, consequently it may easily be conceived to be by far the most blissful habitation of the whole system!"

These strange notions still recur from time to time among persons who invent private cosmologies without benefit of modern astronomy. Shortly after World War II, a German named Gottfried Bueren became an enthusiastic champion of the cold-sun theory, and publicly wagered 25,000 marks that he could not be proven wrong. A group of leading West German astronomers took up this challenge, and submitted the proof. When Bueren refused to accept it, the case was taken to court, and in 1953 the astronomers won the 25,000 marks with costs.

JOSEPH ASHBROOK



These changes in the appearance of a sunspot indicate it is a depression. From W. M. Baxter, March "Journal," British Astronomical Association.

NEW YERKES-McDONALD DIRECTOR

William W. Morgan has been appointed director of Yerkes Observatory, Williams Bay, Wisconsin, and of McDonald Observatory, Ft. Davis, Texas. At the same time, he becomes chairman of the joint astronomy department of the universities of Chicago and Texas.

He succeeds Gerard P. Kuiper, who will become a research professor at the University of Arizona, dividing his time between its Institute of Atmospheric Physics, the astronomy department, and Steward Observatory.

Dr. Morgan has been associated with Yerkes for three decades, and is world-known for his refinements in the classification of stellar spectra. Some of his most recent work was on typing of galaxies.

To assist Dr. Morgan, Frank N. Edmonds, Jr., has been named associate director of McDonald, and Joseph W. Chamberlain, associate director at Yerkes.

MEDAL TO E. J. OPIK

The J. Lawrence Smith medal for 1959 has been awarded by the National Academy of Sciences to Dr. E. J. Opik, University of Maryland, until recently at Armagh Observatory and editor of the *Irish Astronomical Journal*. The medal is granted not more than once every two years for investigations of meteoric bodies, a field in which Dr. Opik has made outstanding contributions.

Why Observe Stellar Eclipses?

ALAN H. BATTEN, *University of Manchester, England**

TOTAL ECLIPSES of the sun for a long time have afforded astronomers their only chances of observing certain solar phenomena. Even though coronagraphs and other special instruments have been developed, solar eclipses still provide opportunity for many important observations. Likewise, for the past half century, eclipses of stars have been recognized as a source of much useful information.

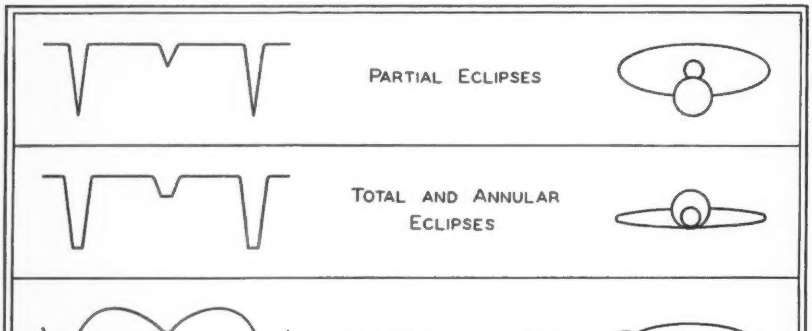
Since the orbital plane of the moon is only slightly inclined to that of the earth, the moon can pass in front of the sun from time to time, producing a solar eclipse. Similarly, stellar eclipses result when the orbital plane of a binary star system is so oriented in space that each component can alternately obstruct the other's light on its way to the earth.

Just as eclipses of the sun can be total, annular, or partial, so can those of the stars; and, as with the sun, total stellar eclipses are the most useful ones to observe. There is one difference, however. For any given binary system, the kind of eclipse is fixed by the position of the orbit in space. Thus, we always observe either successive partial eclipses or total and annular eclipses; in the latter cases the larger star of the pair is first in front of and then behind the smaller one.

Viewed from the earth, these eclipsing systems appear as single stars; how, then, can they be recognized? It is obvious that eclipses must cause variations in the total light that we receive from each pair. Eclipsing binaries, therefore, are usually discovered in the course of any systematic search for variable stars. The characteristic nature of their light curves distinguishes eclipsing stars from other kinds of variables.

In the ideal case, the light of the system is constant for a considerable part of each orbital revolution, because both stars are shining unobstructed. (Only rarely is either component a truly variable star.) Then, as an eclipse begins the system's brightness gradually decreases, for one star is cutting off the light of the other. If the eclipse is total, there is another time of constant but fainter light; then, as the second component emerges from behind the first one, the light of the system increases until it regains its former level.

When the smaller star is in front of the other, the eclipse is annular instead of total. On the other hand, during an eclipse that is only partial, the light varies continuously and increases again as soon as minimum is reached. Light curves of these different possibilities are illustrated here.



In this schematic diagram, five varieties of eclipsing-variable light curves are interpreted. For each case, brightness increases upward, and time toward the right. The hotter star has the greater surface brightness, so the deeper eclipse always occurs when it is behind the other one. The hotter component may be either the larger or smaller of the pair. In the fourth example, the stars are brightest at their centers, darkest at their edges.

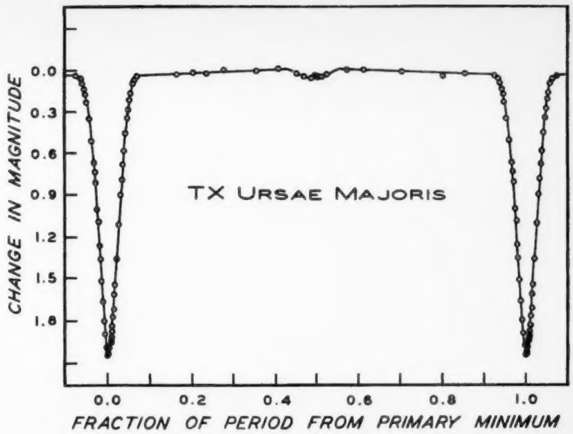
Most eclipsing systems go through a complete cycle of two eclipses in a few days; these are stars that are close to each other and so are traveling quickly in their orbits. Many have periods of less than a day (refer to page 508). On the other hand, a few eclipsing systems have periods of some years; the stars may be widely separated in proportion to their sizes, but their orbits lie very nearly in the line of sight, that is, at right angles to the plane of the sky.

John Goodricke (1764-86) was the first to recognize the typical variation of an eclipsing system. During his short life, he discovered the periodic nature of the light changes of Algol and Beta Lyrae, and suggested that they were caused by eclipses. But it was not until the early part of this century that the work of H. N. Russell and H. Shapley made it possible to begin extracting the information a light curve contains. Since then, the simultaneous development of new computational techniques and of more accurate methods of observation has allowed a wealth of important astrophysical data to be obtained from eclipsing variables.

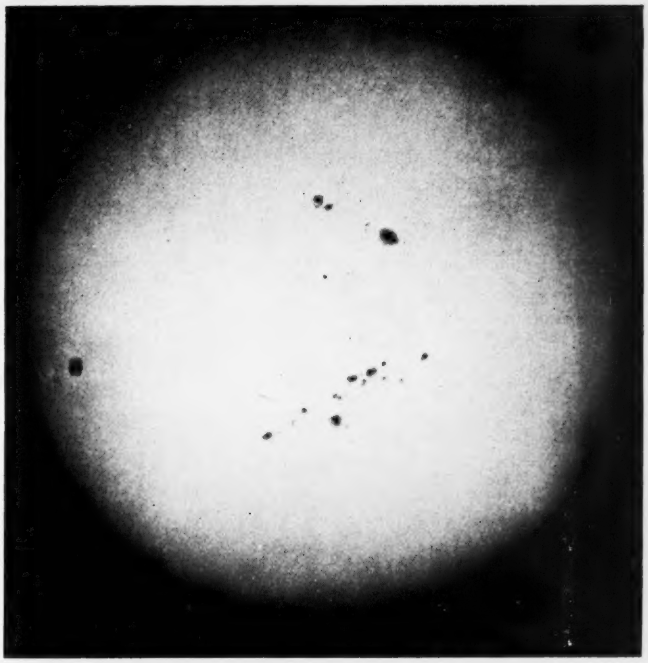
The details of the light curve depend on the geometry of the eclipsing binary system. Thus, the duration of each eclipse, measured as a fraction of the period, must depend on the dimensions of the two stars relative to the diameter of the orbit, as well as on the angle between our line of sight and the orbital plane.

The problem of analyzing a light curve is to calculate these various quantities from the observations. Then a scale "model" of the system can be made, in which all relative dimensions and the orientation of the orbit are known. However, the absolute size of the orbit is un-

*At present on leave of absence to the Dominion Astrophysical Observatory, Victoria, British Columbia, Canada.



Above: The Algol-type eclipsing variable TX Ursae Majoris consists of a main-sequence B8 star and an F2 giant. In this light curve, based on photoelectric observations by C. M. Huffer and O. J. Eggen, small reflection and ellipticity effects are visible. The period of light variation is about 3.06 days.



Right: The limb-darkening of many stars also occurs in the sun, as shown by this photograph, which was made June 16, 1937, by W. M. Kearons, with a refractor.

known, and the geometrical problem is complicated by various physical considerations.

For example, depth of eclipse is determined by the relative luminosities of the two stars. For a totally eclipsing binary, these can be obtained from an inspection of the light curve, but in a partially eclipsing system the fraction cut off from the total light of the eclipsed star adds another unknown quantity. To complicate matters further, stars do not radiate uniformly all over their apparent disks. Photographs of the sun show that it is darkened toward its edge or limb. The limb darkening of stars cannot be observed in this fashion, but when one star moves across the other during an eclipse the amount of light loss is different for equal areas at the center and at the limb of the eclipsed star. This affects the shape of the light curve during partial and annular phases.

Another difficulty is caused by the limited accuracy of photometric observations. Even the best observer with the most modern photoelectric apparatus can do no better than the earth's atmosphere will allow. The many small irregularities that cause the stars to twinkle can wreak havoc with photometric observations. To illustrate this point, it is helpful to recall that a planet's orbit may be calculated from three observed positions. So too, in principle, an orbit for a totally eclipsing system might be deduced from only three brightness measurements at different phases of the eclipse. In practice, however, up to several hundred have to be used to compensate for the limited observational accuracy.

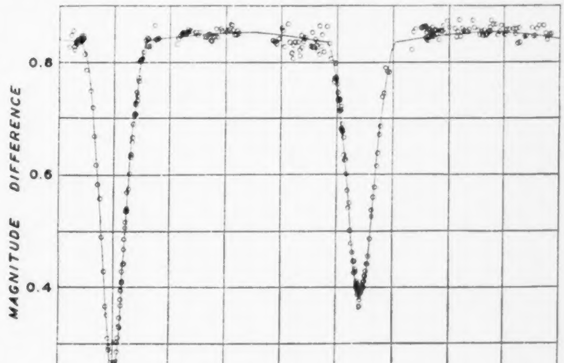
Formidable difficulties are introduced in very close binaries where the components are separated by only a few times their radii. In such a case, tidal distortion of the stars and "reflection" of the light of one by the other produce brightness variations during the time between eclipses. Analysis of the light curve becomes very intricate when an elongated star, whose surface brightness differs from point to point, is partially covered by another distorted star.

Since so many factors influence the shape of a light curve, it is not surprising that unraveling the various effects presents a complex problem. In a strict mathematical sense, it has no exact solution, because some properties of the system have to be assumed before others can be derived. To obtain any solution at all, we have to find the ratio of the radii of the two stars, and the limb-darkening coefficient, which expresses the amount by which the eclipsed star is darkened at the limb. The problem is simpler for a light curve displaying a total eclipse. We can tell immediately which star is the hotter, as it is being eclipsed during the deeper minimum. The relative depths of the primary and secondary eclipses can then be used to give the ratio of the radii. An annular eclipse allows the limb darkening to be determined, for there is a slow variation of light during the annular phase.

In a partially eclipsing system, neither of these aids is available, and it is often necessary to start with an outright guess of these two quantities. Fortunately, the solutions possess the property of convergence. That is to say, if values of the ratio of the radii and limb darkening are assumed, certain information can be derived about the binary system, including improved values of these quantities. Employing them, a new solution can be made. But even this method is useful only if both eclipses are deep and have been well observed. Otherwise, a light curve of a partially eclipsing system is practically useless.

If knowledge can be obtained from stellar eclipses only with so much dif-

F. B. Wood used 323 photoelectric observations for this light curve of RX Herculis. The slight rise and fall in brightness between eclipses indicates elliptical stars, but there is no appreciable reflection effect. This is one of the few cases in which orbital eccentricity (0.018) can be determined from the light curve alone. The system's normal maximum magnitude is 7.3, and the components are of spectral type A0.

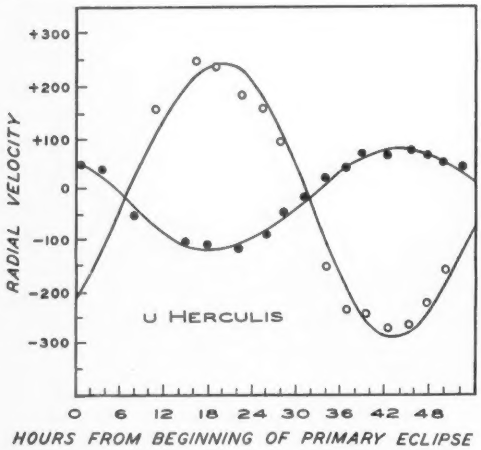


ficulty, why is so much time spent observing them? The answer is that they are the principal source of many kinds of much needed information. From eclipsing binaries a great deal can be learned about the sizes and masses of stars, the structure of stellar atmospheres, and even about the internal structure of stars.

It has already been indicated that relative dimensions of an eclipsing variable may be obtained from its light curve, providing, in effect, a scale model of the system. If the binary has been observed spectroscopically, the radial velocity measurements should give the actual orbital speeds of the component stars, in kilometers per second. From these values, all the linear dimensions of the scale model can be obtained, that is, the actual sizes of the two stars and their distance apart. Furthermore, masses of the components may be determined from a generalized form of Kepler's third law of planetary motion. In addition, the stars' surface temperatures may be estimated from their spectral characteristics. These, combined with their actual dimensions, lead to their intrinsic luminosities or absolute magnitudes, and to an estimate of the distance.

Information about the structure of stellar atmospheres is obtained from the limb-darkening coefficients. With modern procedures, it is possible to observe the same system simultaneously in several colors. The limb darkening of a star is not the same in different colors, varying with wave length in a manner that depends on the opacity of its atmosphere. The most suitable binaries to observe for this effect are those undergoing deep annular eclipses.

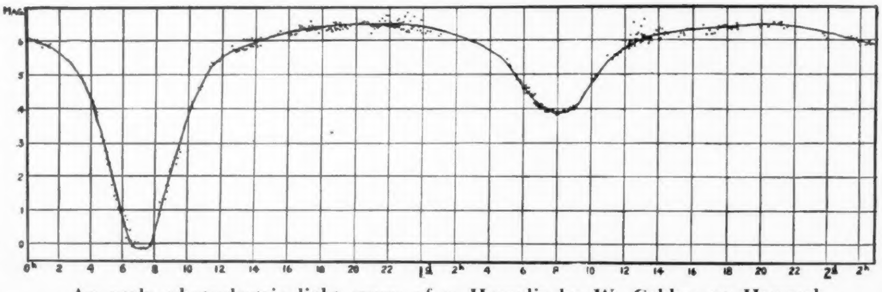
Those double stars that have noncircular orbits aid studies of stellar internal structure. In an elliptical orbit, the speed of each component is not constant and the eclipses are usually not separated by half the period, nor are both eclipses of the same duration. This displacement of one minimum of the light curve with respect to the other, and the difference in duration of minima, depend on the shape or eccentricity of the orbit, and the angle that the major axis makes with the direction to the earth. If the stars are close enough to distort each other, the major axis will rotate slowly, thus changing the form of the light curve. The rate of the rotation depends on the internal structure of the stars themselves. Although velocity curves of spectroscopic binaries also yield this information, eclipsing stars serve as a useful check.



One famous eclipsing binary system is u Herculis, which varies between magnitudes 4.5 and 5.1 in a period of 2.05 days. At the left is its velocity curve, determined by Burke Smith in 1945. The black dots show the motion of the primary component, the circles the secondary. The curves cross when the stars' relative motion in the line of sight is zero, at mid-eclipse. These times correspond to the minima in the light curve plotted below, where the time scale is expanded.

Perhaps it was obvious that eclipsing systems should provide data about the sizes and shapes of their component stars. It may seem surprising, however, that they should also prove to be a source of facts concerning physical conditions in the atmospheres and deep interiors of stars. It is this wide range of information that makes stellar eclipses so important.

It may well be that there are more double than single stars in the sky. Of course, only a tiny fraction of these will be observable as eclipsing binaries, but even this number is so large that there is no hope of discovering all such systems as are believed to exist. And among these, many different types of stars will be found. Thus, from a comparative study much may be learned about stellar evolution — a further reason for observing eclipsing variables.



An early photoelectric light curve of u Herculis by W. Calder, at Harvard.

QUESTIONS... FROM THE S+T MAILBAG

Q. When will Saturn's rings next be presented edgewise to the earth?

A. On December 13, 1965, when the earth will pass through the plane of the rings from north to south. The following year two passages through the ring plane will take place. The rings were last edgewise on September 14, 1950.

Q. How much of the time is the moon above the horizon at the North Pole?

A. Not counting the effect of atmospheric refraction, it is above the horizon at each pole for half of the lunar month, being generally invisible at one pole when visible at the other. It appears about two weeks at a time, and is absent equally long; but it is difficult to detect when the sun is high in the sky during the six-month polar day. In winter, however, the gibbous or full moon is a conspicuous and welcome sight in arctic and antarctic regions.

Q. How much dust and gas is there in interstellar space, compared with the material in the form of stars?

A. In the region of the nearer stars, about a quarter or a fifth as much, but this is uncertain.

Q. How were the constellation boundaries used in modern atlases established?

A. To avoid ambiguity in assigning stars (especially variables) to individual constellations, in 1930 the International Astronomical Union officially defined the boundaries of all 88 star groups. The dividing lines run along circles of right ascension and declination, referred to the epoch 1875.0. This epoch was chosen because it had already been employed in B. A. Gould's delimitation of southern constellations.

Q. What is a Julian day number?

A. Assigned to any date, it is the count of days that have elapsed since January 1, 4713 B.C., which is Julian day 0. This consecutive numbering of days makes it easy to find the exact interval between two widely separated dates, such as of variable star maxima or minima. June 1, 1960, is Julian day 2,437,087.

Q. What is a planetary nebula?

A. It is a luminous body of very rarified gas, having a roundish appearance and superficially resembling a planet's disk as seen in a small telescope. Usually, there is a very faint, hot central star that causes the gas of the nebula to glow, producing a spectrum of bright lines.

W. E. S.

American Astronomers Report

Here are highlights of some papers presented at the 105th meeting of the American Astronomical Society at Pittsburgh, Pennsylvania, April 18-21, 1960. Complete abstracts will appear in the Astronomical Journal.

Symposium on Subdwarfs

Stars along the main sequence of the spectrum-luminosity (H-R) diagram with spectral types later than *A* are generally called dwarfs, the sun being a typical example. Among them, however, are some objects that have low intrinsic luminosities for their spectral classes and therefore lie below the main sequence by amounts ranging up to 1½ magnitudes. These are usually designated *subdwarfs*, though whether they constitute a particular kind of star or a mixture of kinds is not known.

On April 21st at Pittsburgh, five astronomers discussed current problems of the subdwarfs, the symposium moderator being Martin Schwarzschild of Princeton University Observatory. His comments and the question period after each paper served to emphasize the fluid character of present-day thinking concerning subdwarfs, their nature, and their evolution, and indicated very strongly the need for more observations of their parallaxes, motions, and spectra.

The first speaker was the director of Sproul Observatory at Swarthmore College, Peter van de Kamp, who pointed out that we have very few reliable trigonometric parallaxes for subdwarf stars. Many such stars are considerably too faint for the 24-inch Sproul refractor or the 30-inch Thaw refractor of Allegheny Observatory in Pittsburgh (where stars to the 13th magnitude are on the parallax observing program), and even the brighter cases have been insufficiently observed.

Therefore, Dr. van de Kamp's talk was mainly a plea for the use of larger telescopes, including the biggest reflectors, for measurements of distances to these stars. Work has been done with the 100-inch Mount Wilson reflector, but parallax programs require repeated observations at particular times over a number of years, and the large instruments are heavily scheduled for other work. Furthermore, they were not designed to have the extreme optical and mechanical stability desirable in trigonometric measurements.

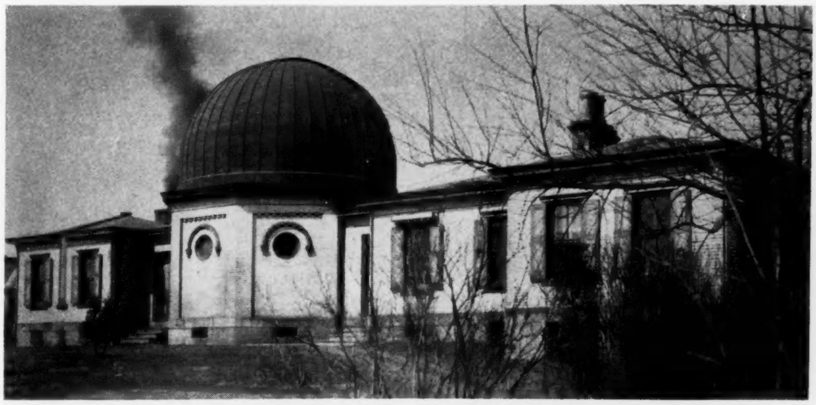
Participating in the Pittsburgh symposium were, from left to right, Thomas L. Swihart, Los Alamos Scientific Laboratory; Pierre R. Demarque, Louisiana State University; Olin J. Eggen, Royal Greenwich Observatory; Martin Schwarzschild (hand on arm), Princeton University Observatory; Lawrence H. Aller, University of Michigan Observatory; and Peter van de Kamp, Sproul Observatory.

Hence, the Sproul astronomer supported strongly the construction of a long-focus astrometric reflector, perhaps 60 inches in aperture, f/10, as proposed by K. A. Strand several years ago. Such an instrument, designed with the special problems of parallax work in mind, could reach stars of apparent magnitude 18 or 18.5 in about seven minutes of exposure time. The effects of temperature changes, which are particularly serious during the early evening observations essential in parallax programs, could be practically eliminated if the primary mirror and secondary optical components were made of quartz, something now entirely feasible.

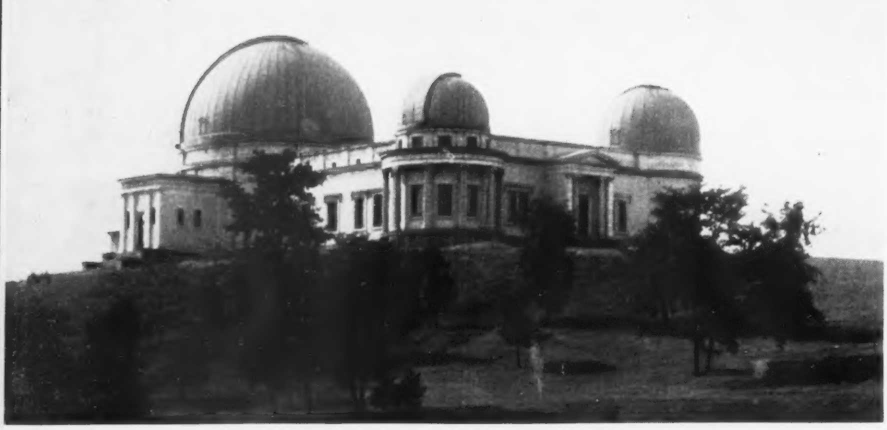
Subdwarfs are in general high-velocity stars, that is, their motions with reference to the center of the Milky Way galaxy differ greatly from the sun's. Perhaps they originated in the galactic center, and indicate some of its characteristics. Thus it becomes very important to determine their individual and collective space motions, and this problem was discussed by Olin J. Eggen, an American-trained astronomer now on the staff of the Royal Greenwich Observatory, Herstmonceux, England.

In order to determine a star's space motion, we must know its parallax, proper motion, and radial velocity (motion in the line of sight). Concerning these quantities, Dr. Eggen said his talk was "really a report on the inadequacy of the data." But known subdwarfs range in apparent magnitude from 4th to 14th, and a few good radial velocities have been obtained, mostly by A. H. Joy with the 100-inch Mount Wilson reflector and by G. Munch and D. M. Popper with the McDonald 82-inch telescope. Several newly discovered subdwarfs in the southern hemisphere have been observed by T. J. Deeming with the 74-inch reflector at Pretoria.

By diligently searching through the material on faint stars, the Herstmonceux astronomer has culled out of all suspected subdwarfs some 200 relatively good cases. About 50 of these have fairly reliable values for radial velocity, proper motion, and three-color photometric data. Distances have been determined for them



The old home of Allegheny Observatory, founded in 1860. It was located about one mile south of the present observatory site. The large dome housed a 13-inch Fitz refractor, with which S. P. Langley in the 1870's made marvelously detailed sunspot drawings. Other Allegheny directors of the first rank were J. E. Keeler, F. L. O. Wadsworth, F. Schlesinger, and H. D. Curtis.



An early view of the present Allegheny Observatory of the University of Pittsburgh, dedicated in 1912. In the largest dome is the 30-inch refractor by Brashear, used for stellar parallaxes; the others house a 31-inch Brashear reflector (stellar spectroscopy), and the 13-inch Fitz telescope.

on the basis of the observed ultraviolet excess in the colors and the relation between this excess and the absolute luminosity that is predicted by the line-blanketing theory of Dr. Eggen and A. R. Sandage.

The space motions obtained for this small sample indicate that some 25 per cent of its stars may belong to two stellar groups, one of which is the Groombridge 1830 group previously studied by Drs. Eggen and Sandage. Also, the velocity vectors for the stars in the sample seem to show that subdwarfs do not partake of the rotational motion of the galaxy as measured for the majority of the stars near the sun. Better faint-star proper motions would help extend analyses of this kind.

The physical and chemical characteristics of the subdwarfs were considered by the last three speakers in the symposium, beginning with Pierre R. Demarque, Louisiana State University, who has calculated theoretical models for the interiors of stars with subdwarf characteristics. He pointed out that the chief problem was to explain the apparent metal-deficient composition of most subdwarfs. His first work concerned star models having 0.6, 0.8, and 1.0 solar mass.

In some cases hydrogen was assumed to comprise 0.999 of the star by weight, with the metals only 0.001, and in other cases the hydrogen was taken as low as 0.75 and the metals as high as 0.1, the remainder being helium. As with other dwarf stars as cool as the sun, the proton-proton reaction – building up helium from hydrogen – was taken as the main source of the star's radiant energy.

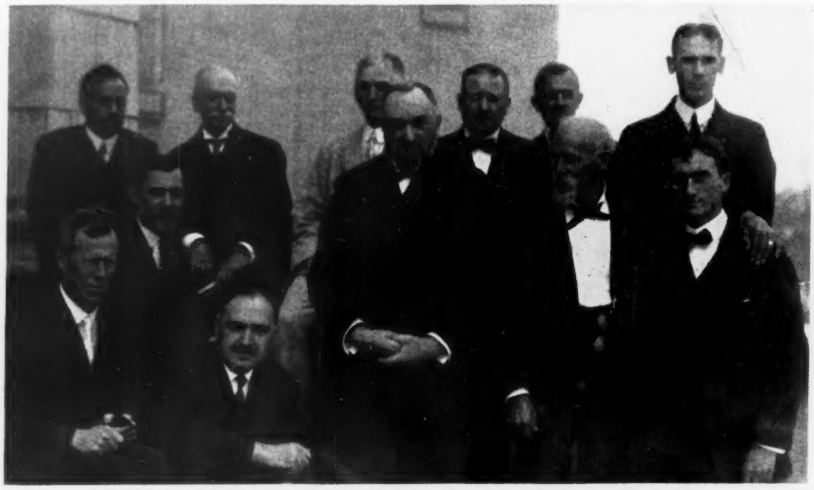
The Demarque models, calculated with the aid of an IBM 650 computer, have a central core in radiative equilibrium and an outer zone in which convection plays a predominant role in the transportation of energy. These models are like those already calculated by D. E. Osterbrock for red dwarf stars. The star's radius depends on the boundary conditions, but the helium content has a strong effect on the total luminosity. For stars of the same mass, a bolometric difference of two magnitudes was found between the extreme cases of all hydrogen and 75 per cent hydrogen, with the metal abundances affecting the results only slightly. Thus, helium content determines such a star's place in the H-R diagram. Unfortunately, these theoretical models can only be compared with the subdwarf stars in a general way, because we do not yet have a first-class mass determination of any individual object of this variety.

Similarly, models for subdwarf atmospheres have been worked out by the fourth symposium speaker, Thomas L. Swihart, of Los Alamos Scientific Laboratory in New Mexico. His examples included cases in which the metal abundances were 1/3, 1/10, and 1/100 those in the sun. The effective surface temperatures were taken at six values between 4,200° and 8,400° K. The logarithm of surface gravity varied between 4.1 and 4.44, the latter being the value on the sun; while the helium content was taken as zero in some cases and as high as 20 per cent in others.

In the visible region of the spectrum, the emitted radiation of the model atmospheres is in satisfactory agreement with that observed in subdwarf stars, but at shorter wave lengths (in the ultraviolet) important discrepancies do exist. The uncertainties are too large to allow a definite conclusion, but it appears that subdwarfs have nearly the same radii, and therefore luminosities, as normal stars of the same temperatures. The excess amount of radiation that these stars have in the ultraviolet makes them appear hotter and earlier in spectral type than they actually are.

The final speaker, Lawrence H. Aller, University of Michigan Observatory, further considered the abundances of elements in subdwarf atmospheres. He pointed out that the faintness of the most interesting subdwarfs makes them difficult objects for spectral analysis, particularly since their spectrum lines are weak owing to the low metal abundances. It is necessary to secure plates with the highest possible dispersion, otherwise the worker will tend to overestimate the equivalent widths of weak lines.

Jesse L. Greenstein has used the coude spectrograph of the 200-inch telescope at Palomar Observatory to secure spectra with a dispersion of 4.5 angstroms per millimeter. These plates provide the best



The American Astronomical Society had not met at Pittsburgh since August 28, 1912, when these members were among those present. At upper left is J. S. Plaskett, Dominion Astrophysical Observatory. Seated left is F. C. Jordan, Allegheny, and just behind him W. S. Eichelberger, U. S. Naval Observatory. In the left foreground is F. Schlesinger, Allegheny, and standing center E. C. Pickering of Harvard. Behind his left shoulder is G. C. Comstock, Washburn Observatory, and at upper right Z. Daniel of Allegheny. J. A. Brashear has his arm around fellow Pittsburgher Stephen Thaw.

data for analysis of two extreme subdwarfs, HD 19445 and HD 140283. Drs. Aller and Greenstein found that the so-called *F* subdwarfs were really *G* stars with temperatures comparable to that of the sun. Furthermore, they differ in metal depletion from one object to another. HD 19445 has a metal abundance only 1/40 that of the sun, whereas for HD 140283 this factor is 1/100.

Can the atmospheric composition differ from that of the stellar interior? Diffusion of gases might produce such an effect, because heavier elements sink with respect to lighter ones. The precise amount of this effect depends on the outer layers of a star. We believe that generally in stars like the sun there is a thick convection zone surrounding the interior core. Diffusion from the lower surface of this zone could result in the loss of heavier atoms, but the process cannot influence the atmospheric layer unless the convection zone is thin.

Quantitative calculations are difficult, but some estimates for the sun have been carried out by Dr. Aller and Sidney Chapman. Their work indicates that in $4\frac{1}{2}$ billion years the abundances of the heavier metals in its atmosphere could be altered by 50 or even 100 per cent. The exact amount of the effect depends on the depth of the convection zone and cannot be determined until this depth is known.

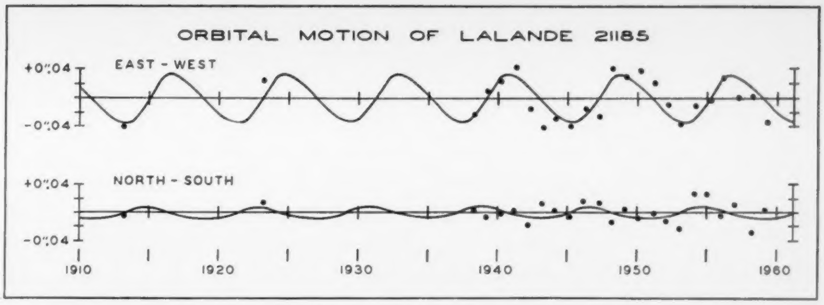
But such diffusion apparently cannot explain the metal deficiencies in subdwarfs, since diffusion depletion should depend smoothly on atomic number, that is, increasing with the weight of the atoms involved. It does not do this in subdwarfs, where, for example, the deficiency of nickel appears to be considerably less than that of iron, while the light element carbon is more strongly depleted than any metal. Therefore, explanations of subdwarf abundances must be sought in terms of processes whereby elements are built up or broken down.

Calculations of mean pressures, masses above the photosphere, and chemical-compound concentrations have also been carried out by Dr. Aller and his co-workers. Next to H_2, the most abundant molecule in cool subdwarfs is water, H_2O; the hydrides are emphasized, and molecules like CN and CH are decreased.

Companion of Fourth Nearest Star

The 7th-magnitude red dwarf Lalande 21185 is only 8.1 light-years distant, and has the unusually large proper motion of 4.8 seconds of arc per year. It is in Ursa Major, at $11^h\ 00^m.6$, $+36°\ 18'$ (1950 co-ordinates).

Since 1912, this star has been photographed with the 24-inch refractor of Sproul Observatory, where in 1944 P. van de Kamp found that the proper motion underwent slight variations, indicating the existence of an unseen companion. Sarah Lee Lippincott now reports new



Deviations of Lalande 21185 from straight-line proper motion are plotted here in right ascension (east-west) and declination (north-south), the wavy curve representing a Keplerian orbit. On the original Sproul Observatory plates, an image displacement of 0.04 second of arc corresponds to only 0.002 millimeter.

facts about this binary system, based on plates taken on 315 nights over the years from 1912 to 1959, which gave data that were analyzed with an IBM 650 computer.

From measurements of the positions of Lalande 21185 with respect to field stars, she first redetermined the parallax and average proper motion. The remaining deviations indicated that the visible star was moving with a period of 8.0 years in an elliptical orbit (eccentricity 0.30) around the center of gravity of itself and the invisible companion.

The primary star has an absolute magnitude of +10.5, so it is intrinsically about 1/200 as bright as the sun. The secondary star may be more than three magnitudes fainter, for it has hitherto escaped detection, even though when farthest apart the two stars should be separated on the sky by more than a second of arc. This considerable brightness difference implies that the companion is of very small mass, perhaps only 1/40 that of the primary, which itself has about 4/10 the sun's.

Thus, the invisible companion is an object of exceptionally small mass, perhaps 1/100 of the sun's and only 10 times Jupiter's. Direct detection, perhaps in the infrared with photoelectric scanning apparatus at one of the times of widest separation of the pair, might permit a straightforward determination of the companion's mass.

Proposed Explanation of Martian Phenomena

Viewed from space, the earth would show striking seasonal changes resulting from the presence in its atmosphere of water, which can exist in solid, liquid, and gaseous form at terrestrial temperatures. In the atmosphere of Mars, there is too little water vapor for spectroscopic detection, but oxides of nitrogen may play an analogous role there. This suggestion has been advanced by C. C. Kiess, S. Karrer, and Harriet K. Kiess, of Georgetown College Observatory.

Absorption of light by gaseous nitrogen peroxide ($NO_2 + N_2O_4$) could account for the low albedo of Mars as observed in green, blue, and violet light. The polar caps of the planet might be attributed to chalky white deposits of solid nitrogen tetroxide (N_2O_4), which in equilibrium with the dioxide has a yellowish tint.

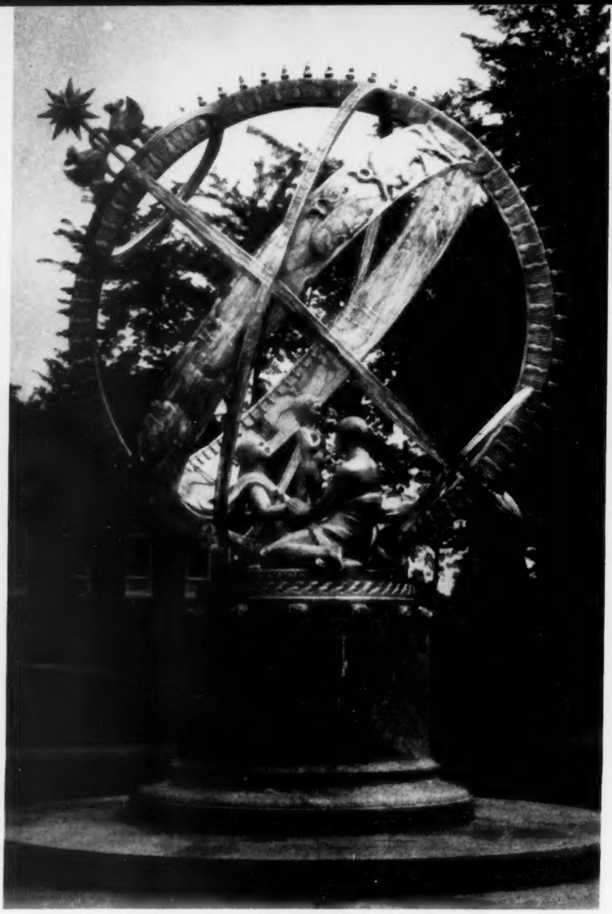
The melting point of nitrogen tetroxide is −11° centigrade or 12° Fahrenheit. This is 20 degrees below the melting point of water, but Mars' average temperature is lower than the earth's. Hence, the dark band observed at the edge of a melting Martian polar cap may be composed of liquid N_2O_4, with nitric oxide (NO) or nitrogen trioxide (N_2O_3) in solution, or both. However, for nitrogen tetroxide to exist as a liquid, the pressure of Mars' atmosphere would have to be about twice as great as its estimated 65 to 75 millimeters of mercury.

Dr. Kiess and his colleagues proposed that heavy N_2O_4 gas spreading toward the Martian equator may cause the seasonal changes in color of the dark regions. Minute crystals of nitrogen oxides in the planet's atmosphere could produce such observed phenomena as haze, transient blue and white clouds, and limb brightening.

One long-standing Martian puzzle has been the *blue clearing* — a temporary transparency of the planet's atmosphere to blue and violet light, which normally cannot penetrate it. If the veiling is due to NO_2, then the clearing may be attributed to polymerization of this gas to N_2O_4, as a result of a cold wave over a large part of the planet. On the other hand, during a heat wave there would be an increase in the NO_2 concentration, perhaps accounting for the yellow clouds, which at times are almost planet wide.

If this interpretation of Martian phenomena is correct, life on that planet is unlikely, because of the toxicity of the oxides of nitrogen.

Dr. Kiess has reported to the National Academy of Sciences spectroscopic observations of Mars with moderate dispersion, finding diffuse absorption features that he identifies as unresolved bands of NO_2. But the question must be studied of whether nitrogen peroxide in the Martian atmosphere would be stable against photochemical decomposition by ultraviolet sunlight. Laboratory data are somewhat contradictory.

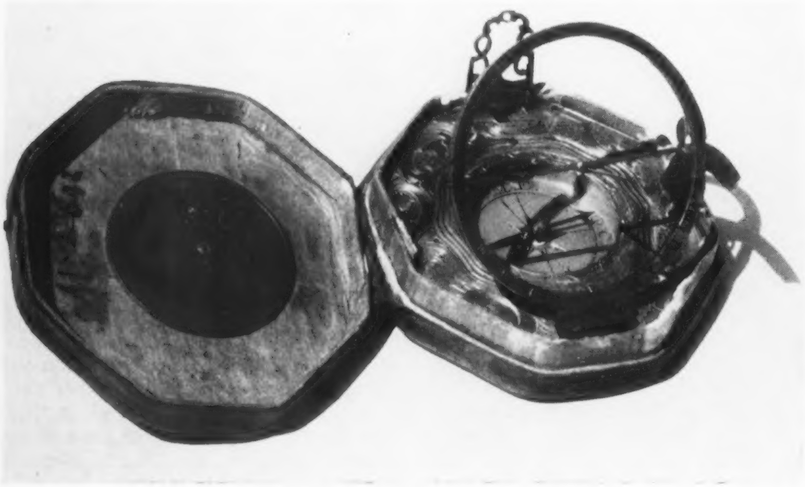


Left: A wall-type sundial, erected at Rapperswil, Switzerland, in 1947-48, that here reads about 11:10 a.m. Right: This ornamented modern armillary sphere at Andover, Massachusetts, can indicate apparent solar time.

A New Universal Sundial Design

HERMANN H. EGGER

RECENT improvements in the design and manufacture of sundials have brought these long-neglected timekeepers to the forefront again as objects of interest and beauty. Modern sundials are both ornamental and useful when placed in gardens, public places, and school recreation grounds, or at observatories, planetariums, and museums.



Made in 1740 by T. Müller, Augsburg, Germany, this four-inch universal sundial's hinged equatorial ring (carrying the shadow pin) can be set for any latitude. In the Southern Hemisphere, shadow travel is reversed.

Usually a sundial remains in a single location throughout the years. It is set to match the latitude of the place and cannot be conveniently moved to another latitude. This is especially true of wall sundials, like the one here in Switzerland shown above, and Newton's sun and moondial at Queens' College, Cambridge (SKY AND TELESCOPE, August, 1957, page 480).

Universal sundials have the advantage of being usable in various places, without the need of a new calculation for each particular location. An old example is the portable dial of 1740 pictured here. Its hinged equator ring is set in accordance with the latitude, and the shadow cast by its central pin shows, for northern latitudes, the apparent solar time of the place.

In my two new universal sundials, there is no central shadow-pin or gnomon, standard time being read by broad shadows from the straight edges of the portions of cylinders that make up the device. This unique construction results in hour intervals that are relatively twice as wide, and therefore more accurate, as those on a sundial with the style on the axis of the cylinder.

The sketch shows the principle by which these dials work. They are erected with the shadow-casting edges parallel to the earth's axis of rotation, that is, with

the edges pointing to the celestial poles. This setting corresponds to the equatorial mounting of a telescope, the cylinder segments being inclined from the vertical by an amount equal to the observer's latitude.

When this orientation is obtained, the sundial is rotated about its central axis until it reads the *standard time* of the moment of setting. As long as the geographical location is not altered, this setting does not change, and automatically compensates for the difference between the observer's longitude and that of the standard-time meridian. The sundial will thus continue to show standard time.

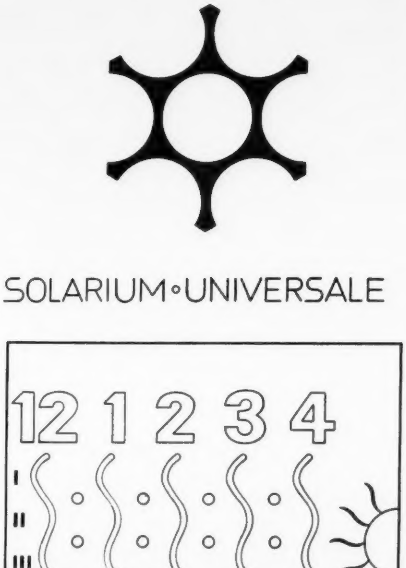
The difference between mean time and apparent time is taken care of by the wavy character of the hour marks, which incorporate the principle of the analemma found on many sundials. They compensate throughout the year for the equation of time — the amount the real sun is running ahead of or behind the mean sun.

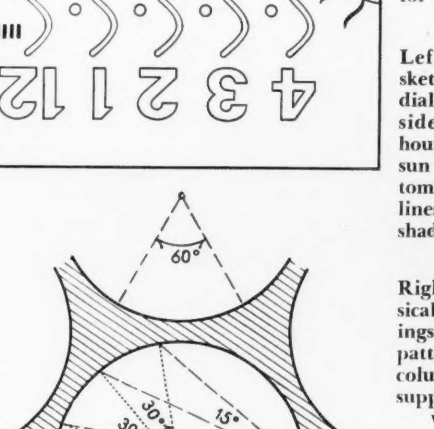
To retain a simple appearance for this model, I have used the numerals I, II, III, IIII to indicate the four quarters of the year, but the large construction of the scale permits marking the month and day down each of the hour curves. It is also possible to add undulating minute lines between the hour lines, to facilitate accurate reading of the time. In a dial of sufficient size, it is thus a simple matter to represent every minute of every day throughout the year.

Each segment takes care of four hours, for those dials made up of six cylinders, or two hours for the 12-cylinder design. Only in polar regions during the summer would the sun cast shadows for continuous 24-hour periods all the way around the dial. The lower row of numerals appears right side up when the device is used in the Southern Hemisphere.

The simple beauty of these sundials makes them very appropriate for garden ornaments. When made of bronze, they are unbreakable and weatherproof, and lend themselves to reproduction in series. They can be built of stone in larger sizes.

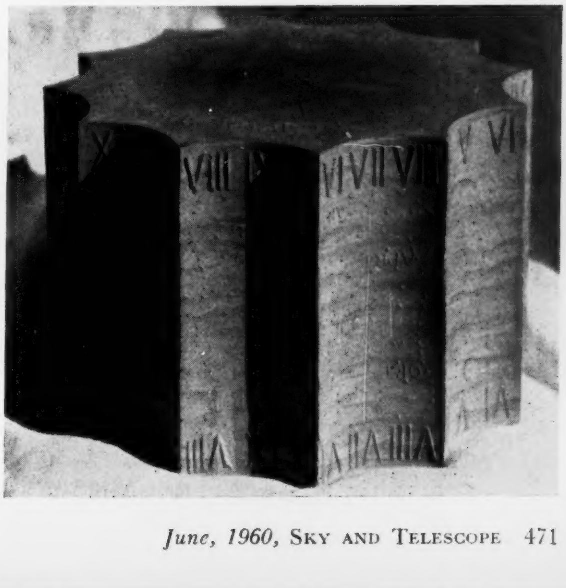
Standard time can be shown anywhere on the earth with this universal sundial designed by Hermann Egger. Each cylindrical section measures four hours, and contains reading curves to compensate for the equation of time. A supporting shaft, inserted in the hollow center, must be aligned to the pole.





Left: Beneath a plan sketch of the Egger sundial is the scheme of the side markings. Three hourly positions of the sun are indicated at bottom right, the dashed lines showing how the shadow moves across the sundial.

Right: Mr. Egger's "classical" design has 12 flutings instead of six, being patterned after Grecian columns. The author supplied all illustrations with this article.



NEWS NOTES

MASS OF SATURN

Last year R. H. Krotkov and R. H. Dicke of Princeton University called attention to a small discrepancy between the observed and predicted motions of Jupiter. This has the form of a small oscillation in the orbital longitude of that planet, amounting at most to only 0.25 second of arc as seen from the sun, and with a period close to the 12 years of Jupiter's revolution.

This effect has now been explained by G. M. Clemence, of the U. S. Nautical Almanac Office, as due to a small error in the adopted value of the mass of Saturn, a body whose attraction greatly influences the motion of Jupiter. Dr. Clemence finds that the discrepancy is removed if Saturn's mass is 1/3499.7 that of the sun.

Previously, the most precise value of the mass of Saturn was 1/3497.6, determined in 1953 by H. G. Hertz from a study of Jupiter's motion. An older figure, 1/3501.6, is still used by the national ephemerides, since there are great advantages in keeping predicted positions of the planets on a strictly uniform basis over many years. Dr. Clemence has reported his study in the February *Astronomical Journal.*

PECULIAR SOLAR OBSERVATIONS EXPLAINED

On January 16, 1959, Swedish astronomer Yngve Ohman was observing the sun at Stockholm Observatory through a telescope equipped with a hydrogen-alpha filter. His attention was caught by a rapidly moving dark object crossing the sun, which on passing the solar limb appeared as a bright surge, visible for about two seconds and extending about two minutes of arc outward from the sun. A month later, a similar observation in white light was made by a colleague of Dr. Ohman's.

It was suspected that these apparent prominences might be caused by very distant jet planes passing in front of a fairly low sun. The Swedish Air Force co-operated in testing this hypothesis, and two transits of a jet plane, distant about 10 kilometers, were observed. In each case apparent prominences were seen, lasting somewhat over one second, and having a brightness similar to that of the solar surface. Dr. Ohman's account appeared in the *Observatory* for December.

C. S. GUM DIES

Colin Stanley Gum, noted 36-year-old Australian radio astronomer and senior lecturer in astrophysics at Sydney University, died on April 28th in a ski accident near Zermatt, Switzerland. He had spent 10 months as a Carnegie fellow at Mount Wilson and Palomar Observatories, and was vacationing on his way to Germany to discuss with manufacturers plans for a 36-inch reflector for Sydney. He was much interested in interstellar polarization and galactic magnetic fields.

Previously, Dr. Gum had served on the International Astronomical Union's subcommission 33b, which established the new system of galactic co-ordinates adopted at the Moscow meeting.

NSF TENTH ANNIVERSARY

Established a decade ago by an act of Congress, and beginning operations in 1951 with an appropriation of $3\frac{1}{2}$ million dollars, the National Science Foundation has become a major stimulus to the development of scientific research and education in this country. The appropriation for the current fiscal year, 1960, is 152 million dollars.

Astronomy has received no small part of NSF funds over the years, beginning with $8,000 in 1952 for basic research grants. In 1959, 51 grants were made, totaling almost two million dollars. During those eight years, 190 project applications were accepted, and over four million dollars expended. Combined with physics, the fellowship awards amounted to six in 1952 and 21 in 1959.

Furthermore, the foundation directly maintains the National Radio Astronomy Observatory at Green Bank, West Virginia, the total budget for construction, operation, and maintenance through 1960 being $10,380,000. Kitt Peak National Observatory, Tucson, Arizona, has the same status, at a cost of $8,445,000 to the present.

A detailed history of NSF's first 10 years is given by its director, Alan T. Waterman, in *Science* for May 6, 1960, page 1341. But on page 1363 of the same issue, there is a disconcerting report that on April 20th the House of Representatives curtailed the foundation's 1961 budget by $31,600,000. The two observatories could receive only pre-operational interim support, and the space telescope project at Kitt Peak would have to be canceled, if the Senate goes along with the House in this matter.

The administration of grants in astronomy by the National Science Foundation has been carried out by these program directors, who gathered for the Kitt Peak National Observatory dedication in March. In order of service they stand right to left: Peter van de Kamp, Sproul Observatory, 1954-55; Mrs. Helen S. Hogg, David Dunlap Observatory, 1955-56; Frank K. Edmondson, Goethe Link Observatory, 1956-57; Geoffrey Keller, formerly of Perkins Observatory, 1957 to present. At the left is Gerard F. Mulders, NSF associate program director for astronomy, formerly with the Office of Naval Research. National Science Foundation photograph.

IN THE CURRENT JOURNALS

APLANATIC CEMENTED DOUBLET DESIGN, by M. G. Dreyfus, R. E. Bishop, and J. E. Moorhead, *Journal* of the Optical Society of America, April, 1960. "The design of a cemented doublet thin lens involves choice of seven independent variables: three radii, two refractive indices, and two reciprocal dispersions. If glass types are arbitrarily selected, then only the three radii remain available as variables for design purposes. The design of a specific lens often requires a specific focal length, achromatic performance, and correction of spherical and comatic aberrations, making a total of four imposed conditions. If we wish to satisfy all four of these requirements we must use one of the four glass constants as a design parameter in addition to the three radii."

PLANETARIUM ENDOWMENT

The sum of $50,000 has been given to Newark Museum by Mr. and Mrs. Leonard Dreyfuss for the maintenance of its planetarium, and to outfit and maintain an observatory, whose construction began this spring. The planetarium is the only one in New Jersey, and has been attended by over 200,000 people since it opened in January, 1953.

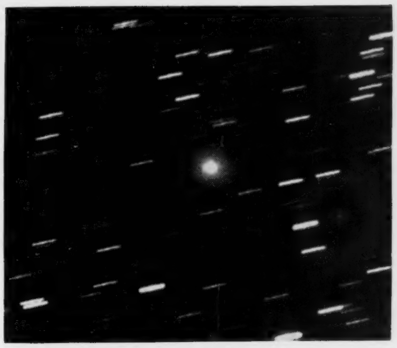
LETTERS

Sir:

Comet Schaumasse, with a period of 8.2 years, was the first comet we observed with the Curtis Schmidt telescope at Portage Lake. With that instrument we took both of the accompanying pictures, the left-hand one on February 23, 1952, a 20-minute exposure on 103a-O emulsion. Now the comet is around again, the right-hand photograph being obtained on April 22, 1960, a 30-minute exposure on IIa-O emulsion.

As printed side by side, the two pictures are in all respects comparable, and show differences in the comet's true size. In 1952, the comet was 12 days after perihelion, in 1960 it was five days past. In 1952, it was 0.31 astronomical unit from the earth, this year 1.27, so we have compensated for this by enlarging the 1960 print four times as much as the 1952 picture. On either print one millimeter equals 27,000 kilometers at the comet's distance, and it is readily apparent that the comet this time had not developed as extensive a coma as eight years ago.

FREEMAN D. MILLER
University of Michigan Observatory
Ann Arbor, Mich.



Periodic Comet Schaumasse in 1952 (left) and 1960, enlarged 1¼ and five times, respectively, from plates taken with the University of Michigan's 24-inch Schmidt telescope. The reproduction scale is 27,000 kilometers per millimeter for both pictures. When the 1960 exposure was made, the comet was about magnitude 12.

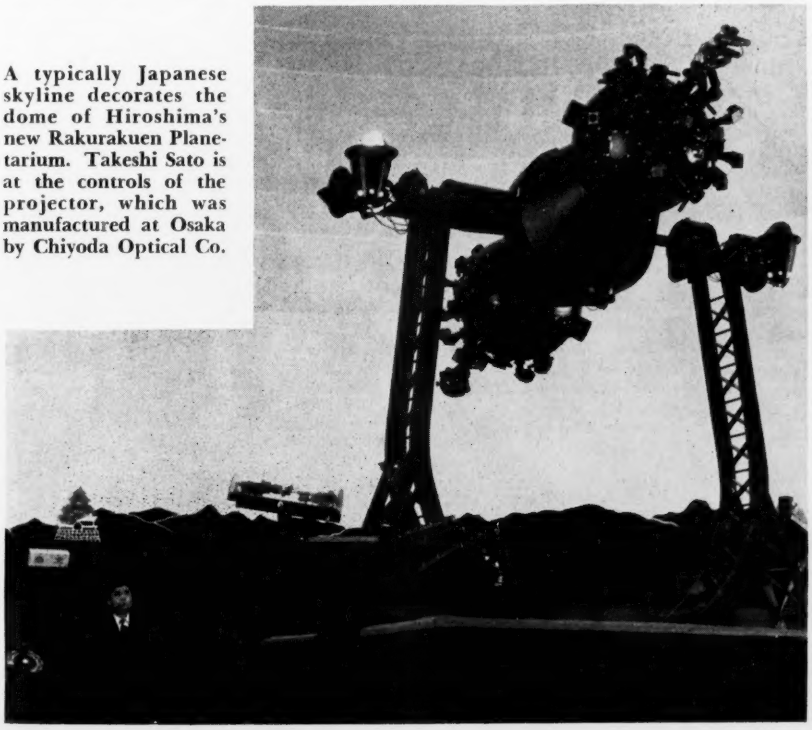
Sir:

On March 19th, a large planetarium was opened at the Rakurakuen Recreation Ground just outside of Hiroshima, Japan. The 60-foot theatre chamber accommodates about 300 persons.

The planetarium instrument, which was designed by M. Nobuoka, optically projects about 8,000 fixed stars and other objects. An unusual characteristic is that the fixed stars twinkle. The 24 brightest stars are shown separately, to make their images smaller and more intense. Supplementary projectors are used for demonstrating the motion of the sun, moon, and planets, and for special effects such as aurorae, artificial satellites, and variable stars.

The planetarium has a small museum for astronomical photographs and exhibits. Visitors are always welcome.

TAKESHI SATO
Rakurakuen Planetarium
Itsukaichi, Hiroshima, Japan



A typically Japanese skyline decorates the dome of Hiroshima's new Rakurakuen Planetarium. Takeshi Sato is at the controls of the projector, which was manufactured at Osaka by Chiyoda Optical Co.

Sir:

The United States committee for the International Union of the History and Philosophy of the Sciences is participating in a world-wide inventory of scientific instruments of historical importance. Our first step is to determine the present locations of such instruments.

For the purposes of this survey, an instrument of historical importance is defined as one which has been the basis of an important discovery. As chairman of the committee, I would be grateful for suggestions from SKY AND TELESCOPE readers as to specific instruments deserving inclusion in this inventory, and for any details about their present custody.

ROBERT P. MULTHAUF
Department of Science and Technology
U. S. National Museum
Washington 25, D. C.

Sir:

Venus has been in the news for a considerable length of time, but the persons concerned with her have been careful not to jeopardize her classical attributes. Recently, however, ballisticians, electronics engineers, and scientists of the new, unclassical generation have shown an active interest in Venus, and this has resulted in a flurry of writings in which the adjective *Venusian* has made its ugly debut.

I have no objection to the creation of new words, which are often needed to cope with an expanding technology. *Jeep, bazooka,* and even *sputnik* are acceptable words, but *Venusian* jars my classical nerves. By the same derivative process, we would have *Jupiterian, Marsian,* and *Uranusian!*

The 1955 *Oxford Universal Dictionary* has the entry: "*Venerean.* 1. connected or associated with, relating or pertaining to Venus or her service. . . ." If one has to use an adjective in connection with Venus, this is it, and *honi soit qui mal y pense.* Those who wish may avoid it entirely by rephrasing the sentence, for example, "the Venus atmosphere" or "the atmosphere of Venus."

LUIGI G. JACCHIA
Smithsonian Astrophysical Observatory
Cambridge 38, Mass.

EDITOR'S NOTE: We agree with Dr. Jacchia's objection to *Venusian.* A suitable substitute, used in astronomical literature for nearly a century, is the adjective *Cytherean,* for which the Merriam-Webster unabridged dictionary gives the meaning "Of or pertaining to the goddess Aphrodite or Venus, or the planet Venus."

The Earth's Shadow Size at the March Lunar Eclipse

JOSEPH ASHBROOK, *Harvard College Observatory*

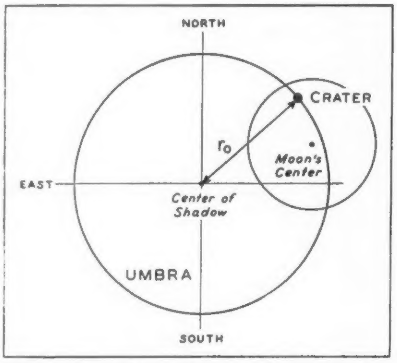
AMATEUR ASTRONOMERS enthusiastically responded to the request on page 230 of the February SKY AND TELESCOPE for special observations of the March 13, 1960, eclipse of the moon, for the purpose of determining the enlargement of the earth's umbral shadow.

Our globe's shadow has two concentric parts. The dark, inner shadow or *umbra* was about 1.4 degrees in diameter, at the moon's distance. Surrounding it was the lighter *penumbra*, 2.5 degrees in diameter. The moon, 0.5 degree in diameter, passed nearly centrally through this pattern, and thus served as a probe whose brightness and color indicated conditions within the shadow.

Everyone who has watched a lunar eclipse attentively has noticed how the darkness of the shadow decreases progressively from its center out to the indefinite penumbral fringe. The eye, however, sees a fairly definite apparent edge to it, whose radius marks the distance from the center where the shadow gradient is steepest.

This apparent radius is always roughly two per cent larger than would be computed from the geometry of the eclipse, if no allowance is made for the earth's atmosphere, which has a profound influence on the shadow. The amount of enlargement is not the same at all eclipses, and may perhaps serve as a geophysical index number, characterizing the state of the earth's atmosphere.

The simplest kind of observation to evaluate this enlargement is recording the times of contacts during an eclipse. Consider, for example, contact I, when the moon begins to enter the umbra, and the lunar disk is externally tangent to the umbra's outline. We can deduce the umbral radius by calculating the angular distance of the moon's center from the shadow center, and subtracting the lunar radius.



How the radius of the earth's umbra is found from crater contact times at an eclipse of the moon.

This kind of analysis has been made for 100 observed times of the four contacts at the March 13th eclipse. In the following summary, for each contact are given the number of timings, the average of the observed times, its mean error in seconds of time, and the enlargement of the umbra, expressed as a percentage excess over the theoretical value.

Contact	*No.*	*UT*	*m.e.*	*Enlargement*
I	26	6:38:29	±07	1.6%
II	39	7:40:25	±05	2.8
III	21	9:15:42	±10	3.3
IV	14	10:17:46	±12	3.0

The enlargement comes out too small for contact I, since timings of that phenomenon tend to be a little late, and similarly observations of IV may tend to be systematically early. Giving half weight to the results from those contacts, and unit weight to contacts II and III, we obtain 2.8 per cent as the average amount of the enlargement of the umbra.

More precise results are given by a second observational method, which consists of noting when particular craters appear to enter or leave the umbra. In all, 203 crater timings are analyzed here. Some discordant observations have been omitted that appear to have been affected by crater misidentifications, errors of record, or overcast sky. Also omitted are a number of incomplete or indefinite observations.

The manner in which the umbra's radius was found from each timing is indicated by the accompanying diagram. The location of the moon's center with respect to the shadow center can be calculated for the time of observation. Next, the position of the crater relative to the moon's center is known, proper allowance being made for libration. Finally, these data give the crater's distance from the shadow midpoint, which is the observed umbral radius, r_o.

In the actual calculations, I used the formulas published by the Russian astronomer S. Kosik in 1940. These take account of the ellipticity of the earth, which affects the shadow's shape. The first step in all the reductions was to convert the observed Universal times to Ephemeris times, by adding 35 seconds.

The accompanying table reports 203 crater timings. Each Universal time is followed by the deduced value of r_o, expressed as a fraction of the equatorial radius of the earth. The last column gives the difference $(r_o - r_c)$ between the observed and computed radii of the umbra.

The average of all these $(r_o - r_c)$ values is $+0.0194 \pm 0.0004$ earth radius. Dividing this by r_c, we find that the enlargement of the umbra was 2.71 ± 0.06 per cent at this eclipse. This agrees well with the 2.8 per cent from the timings of the four contacts.

Evidently the March, 1960, eclipse had a more marked umbral enlargement than did some other recent ones. On November 17-18, 1956, the value was 2.15 per cent, from 42 crater timings reported to SKY AND TELESCOPE (see page 196, Febru-

At Chicago, Illinois, on March 13th, the totally eclipsed moon was photographed by F. K. Leisch with a 3½-inch Questar telescope. He used a 1-inch eyepiece, Praktica camera, and Tri-X film, each exposure two minutes long. At the left, the moon is shown at 8:35 Universal time (just after midtotality), while third contact, at 9:16, is at the right. The moon is still within the umbra, but very bright along its southeastern edge.

ary, 1957). Also, Czech observers found only 1.8 per cent for the May 13-14, 1957, eclipse (March, 1959, issue, page 269).

The next opportunity for amateurs in the United States to make similar observations will be during the September 5, 1960, total lunar eclipse, which takes place before and during dawn on the morning of Labor Day.

ENTRANCE INTO UMBRA

Crater	Obs'r.	UT	Observed Rad. (r_o)	Diff. ($r_o - r_c$)
Riccioli	Sn	6:42.2	0.735	+0.018
Grimaldi	Jo	6:43.3	.751	.035
Riccioli	Lu	6:43.7	.722	.005
Grimaldi	Gr	6:44.0	.745	.029
Grimaldi	Hu	6:44.0	.745	.029
Grimaldi	Sn	6:44.2	.743	.027
Grimaldi	Bt	6:44.2	.743	.027
Grimaldi	Fr	6:44.2	.743	.027
Grimaldi	No	6:44.2	.743	.027
Reiner	Bw	6:44.8	.736	.019
Herodotus	Hu	6:45.0	.742	.025
Grimaldi	Bn	6:45.1	.734	.018
Grimaldi	Lu	6:45.3	.732	.016
Herodotus	Bt	6:45.5	.738	.021
Herodotus	Gr	6:45.9	.734	.017
Aristarchus	No	6:46.0	.740	.023
Aristarchus	Bu	6:46.2	.739	.022
Aristarchus	Lu	6:46.4	.736	.019
Aristarchus	Kr	6:46.5	.735	.018
Aristarchus	Bt	6:46.8	.733	.016
Aristarchus	Gr	6:46.8	.733	.016
Aristarchus	Bw	6:47.8	.723	.006
Kepler	Fo	6:50.2	.744	.027
Kepler	Hu	6:50.4	.742	.025
Kepler	Lu	6:51.7	.731	.014
Hansteen	Gr	6:51.9	.737	.021
Letronne	Bt	6:53.1	.740	.023
Euler	Bw	6:54.2	.732	.015
Gassendi	Hu	6:56.2	.743	.026
Gassendi	No	6:56.5	.741	.024
Lambert	Bw	6:57.2	.737	.020
Gassendi	Gr	6:57.4	.734	.017
Copernicus	Kr	6:57.7	.750	.033
Gassendi	Bt	6:57.8	.731	.014
Copernicus	Ay	6:58.0	.747	.030
Copernicus	Fo	6:58.2	.745	.028
Copernicus	Hu	6:58.4	.743	.026
Copernicus	Ci	6:58.6	.741	.024
Copernicus	Ba	6:58.7	.740	.023
Copernicus	Is	6:58.7	.740	.023
Copernicus	Bt	6:58.8	.739	.022
Copernicus	Gr	6:59.0	.738	.021
Copernicus	Lu	6:59.0	.738	.021
Copernicus	Ri	6:59.1	.737	.020
Copernicus	Sa	6:59.1	.737	.020
Copernicus	Bw	6:59.2	.736	.019
Copernicus	Bl	6:59.2	.736	.019
Copernicus	Te	6:59.2	.736	.019
Copernicus	Sh	6:59.7	.732	.015
Copernicus	Fi	6:59.9	.730	.013
Copernicus	Bn	7:00.0	.728	.011
Copernicus	Bu	7:00.0	.728	.011
Timocharis	Bt	7:00.8	.735	.018
Timocharis	Bw	7:01.1	.732	.015
Plato	Fo	7:01.2	.740	.023
Plato	Bt	7:01.4	.738	.021
Timocharis	Sh	7:01.5	.728	.011
Plato	Ri	7:01.5	.737	.020
Plato	Cn	7:01.5	.737	.020
Plato	Fr	7:01.5	.737	.020
Plato	Ci	7:01.6	.737	.020
Plato	Ay	7:01.6	.737	.020
Plato	Sa	7:01.6	.737	.020
Plato	Ba	7:01.7	.736	.019
Plato	Gr	7:01.8	.735	.018
Plato	Lu	7:01.9	.734	.017
Plato	Te	7:01.9	.734	.017
Plato	Cu	7:02.0	.733	.016
Plato	Is	7:02.1	.732	.015
Plato	De	7:02.2	.731	.014
Plato	Hu	7:02.3	.731	.014
Plato	No	7:02.7	.727	.010
Plato	Bw	7:02.7	.727	.010
Plato	Bu	7:02.8	.726	.009
Plato	Bn	7:02.9	.725	.008
Plato	Fi	7:03.1	.724	.007
Schickard	Hu	7:04.1	.736	.019
Archimedes	Bt	7:04.1	.741	.024
Archimedes	Lu	7:04.2	.740	.023
Schickard	Bt	7:05.0	.731	.014
Autolycus	Gr	7:06.6	.740	.024
Aristoteles	Hu	7:10.4	.737	.020
Linné	Cn	7:10.8	.744	.027
Eudoxus	Hu	7:11.0	.746	.029
Schiller	Hu	7:11.4	.740	.023
Pitatus	Gr	7:12.0	.733	.016
Alphonsus	Hu	7:12.1	.738	.021
Pitatus	Lu	7:12.3	.730	.013
Pitatus	Bw	7:12.8	.726	.009
Menelaus	Sn	7:15.4	.740	.023
Menelaus	Sg	7:15.4	.740	.023
Menelaus	Kr	7:15.5	.739	.022
Tycho	No	7:15.9	.745	.028
Tycho	Sg	7:15.9	.745	.028
Tycho	Hu	7:16.7	.738	.021
Tycho	Ri	7:16.8	.737	.020
Tycho	Sa	7:16.8	.737	.020
Tycho	Fo	7:16.9	.736	.019
Tycho	Cm	7:16.9	.736	.019
Tycho	Is	7:17.0	.736	.019
Tycho	Ay	7:17.0	.736	.019
Tycho	Ba	7:17.1	.735	.018
Tycho	Fr	7:17.3	.734	.017
Tycho	Cu	7:17.3	.734	.017
Atlas	Cn	7:17.4	.752	.035
Tycho	Gr	7:17.4	.733	.016
Tycho	Te	7:17.6	.732	.015
Tycho	Le	7:17.6	.732	.015
Tycho	Ci	7:17.6	.732	.015
Tycho	Bt	7:17.6	.732	.015
Tycho	Lu	7:17.6	.732	.015
Tycho	Fi	7:17.8	.730	.013
Tycho	Bw	7:17.8	.730	.013
Tycho	Cs	7:17.8	.730	.013
Tycho	Bl	7:17.8	.730	.013
Posidonius	Lu	7:19.9	.741	.024
Maginus	Hu	7:20.6	.737	.020
Macrobius	Bw	7:24.8	.752	.035
Macrobius	Hu	7:25.2	.750	.033
Proclus	No	7:27.2	.747	.030
Cleomedes	Hu	7:27.8	.734	.017
Fracastorius	Bw	7:29.5	.738	.021
Fracastorius	Hu	7:29.8	.736	.019
Gutenberg	Lu	7:31.2	.733	.016
Gutenberg	Hu	7:32.5	.722	.005
Goclenius	Gr	7:32.7	.744	.027
Langrenus	Gr	7:36.1	.751	.034
Langrenus	Hu	7:36.4	.749	.032
Furnerius	Ha	7:36.8	.748	.031
Wrottesley	Ha	7:36.9	0.737	+0.020

EXIT FROM UMBRA

Crater	Obs'r.	UT	Observed Rad. (r_o)	Diff. ($r_o - r_c$)
Riccioli	Gr	9:17.6	0.743	+0.027
Riccioli	Lu	9:18.1	.747	.031
Grimaldi	St	9:18.3	.723	.006
Grimaldi	Cl	9:18.5	.724	.007
Grimaldi	Jo	9:18.5	.724	.007
Grimaldi	Gr	9:18.8	.729	.012
Grimaldi	Lu	9:18.8	.729	.012
Grimaldi	Bt	9:18.9	.729	.012
Schickard	Bt	9:23.3	.735	.020
Billy	Ha	9:24.2	.735	.019
Mersenius	Bt	9:25.0	.744	.028
Gassendi	Lu	9:26.7	.726	.010
Gassendi	Bt	9:28.0	.736	.020
Gassendi	Ha	9:28.2	.738	.022
Aristarchus	Kr	9:28.3	.731	.016
Gassendi	Gr	9:28.4	.740	.024
Aristarchus	No	9:28.4	.732	.017
Aristarchus	Ha	9:28.5	.733	.018
Aristarchus	Gr	9:28.7	.734	.019
Aristarchus	Bt	9:28.9	.736	.021
Aristarchus	Lu	9:29.6	.743	.028
Kepler	Ha	9:30.7	.734	.017
Kepler	Cl	9:30.8	.734	.017
Kepler	Bt	9:31.2	.738	.021
Kepler	Gr	9:31.2	.738	.021
Kepler	Lu	9:31.4	.739	.022
Bullialdus	Ha	9:36.2	.735	.018
Tycho	Cl	9:38.4	.729	.013
Tycho	Fr	9:38.4	.729	.013
Tycho	Lu	9:38.4	.729	.013
Tycho	No	9:38.5	.731	.015
Tycho	Bt	9:38.7	.732	.016
Tycho	Ha	9:38.8	.734	.018
Tycho	Gr	9:39.1	.736	.020
Tycho	Ri	9:39.2	.736	.020
Tycho	De	9:39.2	.736	.020
Pitatus	Bt	9:39.5	.735	.019
Copernicus	Lu	9:39.8	.735	.019
Copernicus	Bt	9:39.9	.736	.020
Copernicus	Ha	9:39.9	.736	.020
Copernicus	Te	9:40.1	.737	.021
Copernicus	Ri	9:40.4	.739	.023
Copernicus	Gr	9:40.5	.740	.024
Tycho	Fi	9:40.5	.745	.029
Straight Range	Bt	9:41.9	.737	.021
Timocharis	Ha	9:43.8	.732	.017
Eratosthenes	Lu	9:43.9	.732	.017
Timocharis	Bt	9:44.2	.737	.022
Eratosthenes	Ha	9:44.5	.735	.020
Plato	Ri	9:45.0	.734	.017
Plato	No	9:45.1	.735	.018
Plato	Ha	9:45.1	.735	.018
Plato	Cn	9:45.1	.735	.018
Plato	Bt	9:45.2	.735	.018
Plato	De	9:45.2	.735	.018
Plato	Lu	9:45.3	.737	.020
Plato	Te	9:45.4	.738	.021
Plato	Gr	9:45.7	.740	.023
Plato	Cu	9:46.4	.746	.029
Alphonsus	Ha	9:47.2	.736	.020
Archimedes	Bt	9:48.6	.726	.009
Aristillus	Bt	9:50.6	.738	.021
Aristillus	Gr	9:50.8	.740	.023
Cassini	Bt	9:51.6	.740	.023
Manilius	Ha	9:55.0	.732	.015
Linné	Ha	9:55.5	.738	.021
Manilius	Lu	9:56.2	.743	.026
Menelaus	Bt	9:58.4	.738	.021
Menelaus	Kr	9:58.5	.738	.021
Plinius	Bt	10:01.1	.728	.011
Plinius	Gr	10:02.4	.739	.022
Posidonius	Bt	10:02.5	.738	.021
Proclus	No	10:10.8	.736	.019
Proclus	Bt	10:10.8	0.736	+0.019

KEY TO OBSERVERS

Ay, H. Ayala Rodriguez, 6-inch reflector, Ciudad Juarez, Mexico; *Ba,* R. Barnes, 6-inch reflector, Trinidad, W. I.; *Bl,* J. Blair, 18½-inch refractor, 200x, Evanston, Ill.; *Bn,* H. Bondy, 3½-inch reflector, 60x, Flushing, N. Y.; *Bt,* E. Both, 8-inch refractor, 40x, Buffalo, N. Y.; *Bu,* A. Burek, 3-inch refractor, Hempstead, N. Y.; *Bw,* J. Brownridge, 3-inch refractor, 12x, Jackson, Miss.

Ci, R. Citron, 5-inch refractor, Jupiter, Fla.; *Cl,* W. Coleman, 4½-inch reflector, 40x, Phoenix, Ariz.; *Cm,* Mrs. W. Cameron, 3½-inch catadioptric, 80x and 160x, Adel-

phi, Md.; *Cn,* R. Conklin and F. Clark, 6-inch reflector, 60x, Richmond, Va.; *Cs,* Case Astr. Soc., Cleveland, Ohio; *Cu,* F. Cushing, 6-inch reflector, Richmond, B. C.; *De,* C. Dean, 4¼-inch reflector, Narberth, Pa.; *Fi,* J. Fitzpatrick and K. Savage, 3½-inch reflector, 60x and 125x, New York, N. Y.; *Fo,* G. Foley, 6-inch reflector, Philadelphia, Pa.; *Fr,* M. Francis and others, 6-inch reflector, 40x, and 4-inch reflector, 60x, Bellwood, Ill.

Gr, H. Grams, 4-inch reflector, 50x, Gillette, Wyo.; *Ha,* W. Hartmann, 6-inch refractor, 90x, State College, Pa.; *Hu,* Hudson County Astr. League, 5 telescopes, Union City, N. J.; *Is,* C. Isbell, 3½-inch reflector, 60x, El Paso, Tex.; *Jo,* E. Jones and G. Vetrovec, 4-inch reflector, 47x, Sandston, Va.; *Kr,* J. Krebs, 6-inch reflector, 40x, Washington, D. C.; *Le,* E. Lerner, 7 × 50 binoculars, Pikesville, Md.; *Lu,* H. Luft, 2-inch refractor, 48x, Oakland Gardens, N. Y.

No, E. Nordeen, 8-inch reflector, 85x and 52x, St. Paul, Minn.; *Ri,* Richmond Ass'n. of Jr. Astronomers, 8-inch reflector, Richmond, Va.; *Sa,* Sangamon Astr. Soc., several telescopes, Springfield, Ill.; *Sg,* Star Gazers Club, several telescopes, Northfield, Minn.; *Sh,* J. Shannon, Kittanning, Pa.; *Sn,* J. Sunshine, 4-inch reflector, 65x, University Heights, Ohio; *St,* J. Sutcliffe, 20 × 65 binoculars, San Jose, Costa Rica; *Te,* Terre Haute Astr. Soc. and Moonwatch Team, Terre Haute, Ind.

SMALL PLANETARIUM IN ARIZONA

After reading David DeBruyn's description of his basement planetarium in this department last November, I decided to develop a similar project. I also punched holes in a small Spitz, Jr., planetarium instrument to project the fainter stars of the constellations and Milky Way. A commercial opaque projector was purchased for special effects.

At first I planned to house the setup in my basement, but I decided to put it in an old grain shed on our farm. This has worked out very well.

Shows are changed monthly, and anyone in the area is welcome to visit.

GILFORD C. BISJAK, JR.
P. O. Box 121
Chino Valley, Ariz.

THIS MONTH'S PROGRAMS

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. June 4, Dr. G. F. W. Mulders, National Science Foundation, "Optical Phenomena in the Earth's Atmosphere."

STEUBENVILLE, OHIO

The Ohio Valley Amateur Astronomers has eight members. Its president is Fred A. Donaldson, P. O. Box 270, Steubenville, Ohio.

GLEN BURNIE, MARYLAND

Nineteen amateurs have formed the Chesapeake Astronomical Society. Further information is available from Mike Meyerhoff, 1045 Thomas Rd., Glen Burnie, Md.

Amateur Astronomers

NORTHEAST REGION HOLDS NEW YORK CITY CONVENTION

NINETY-ONE amateurs from 11 societies attended the Northeast regional meeting of the Astronomical League at New York City on April 30th and May 1st. The Junior Astronomy Club was the host.

Dr. Robert I. Wolff, professor of astronomy at the City College of New York, spoke on frontiers in astronomy, at the convention banquet in the Hotel New Yorker. He discussed the possibility that studies of the neutrinos that come from the sun may give us information on the processes going on deep in its interior.

Included in the meeting was a trip to the American Museum-Hayden Planetarium for a showing with the new Zeiss projector.

Officers for the coming year are Mrs. Helen Velardi, New Haven, Connecticut, chairman; Edgar Everhart, Mansfield Center, Connecticut, vice-chairman; John Welch, W. Springfield, Massachusetts, treasurer; and Walter Whyman, Batavia, New York, secretary.

Ralph Dakin announced plans for the regional meeting at Rochester, New York, in May, 1961, which will include a visit to Bausch and Lomb Optical Co. to witness a pouring of optical glass.

NORTHWEST CONVENTION DATE CHANGED

The Northwest Region of the Astronomical League will meet at the University of Oregon in Eugene on July 30-31, instead of the beginning of the month, as originally announced. The registration fee of $1.00 per individual or $1.75 for a family may be sent to M. McDerman, 3625 Willamette St., Eugene, Ore., from whom housing information is obtainable.

AAVSO SPRING MEETING

The 49th spring meeting of the American Association of Variable Star Observers is scheduled at the American Museum-Hayden Planetarium in New York City, May 27-30.

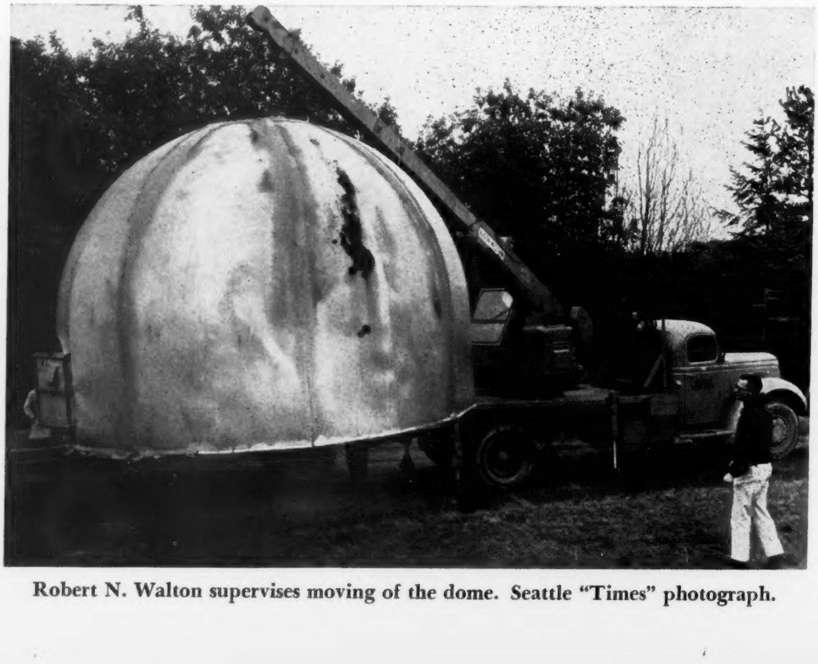
OLD BATTLESHIP IS SOURCE FOR AN OBSERVATORY DOME

A LARGE sheet-metal dome that sheltered a pair of antiaircraft guns aboard the mothballed battleship U. S. S. *Colorado* will be used for an observatory to be constructed at Camp William G. Long in Seattle, Washington.

Seventeen feet in diameter and weighing about 1,900 pounds, the dome was purchased for $50 from the salvage company that is scrapping the ship. Robert N. Walton, camp director, estimates its conversion cost as about $300. It will be equipped with a slit and is to rotate on steel wheels on a circular track, the sides of the cement-block building to be 10 feet high.

The entire observatory project will cost around $2,000, with all of the money and parts donated by interested business firms. Members of the Seattle Amateur Astronomical Society have offered to build a 12½-inch Cassegrainian telescope, fitted with a Polaroid-type camera.

The observatory will be operated primarily for children by the Seattle park department. Camp Long is located on a 70-acre tract within the city limits. About 24,000 youngsters visit it each year.



Robert N. Walton supervises moving of the dome. Seattle "Times" photograph.

ASTRONOMICAL LEAGUE 1960 CONVENTION PLANS

REGISTRATION is now open for the general convention of the Astronomical League at Haverford College, outside Philadelphia, Pennsylvania, over Labor Day weekend, September 3-5, 1960. Until August 15th, the fee is $1.00 per person; $1.50 after that date.

Housing will be available in the college dormitories for $5.00 a night per individual, each room accommodating two persons. There will be separate floors for men and women. Registration fees and room reservations should be sent to General Convention Astronomical League, c/o Franklin Institute, Philadelphia 3, Pa.

Amateurs desiring program time are requested to submit outlines of their proposed talks to the following:

Junior session — Tim Wyngaard, 5202 Hammersley Rd., Madison, Wis.

General session — James H. Conklin, East Ave., Mullica Hill, N. J.

Association of Lunar and Planetary Observers session — Walter Haas, Pan American College Observatory, Edinburg, Tex.

Instrument session — George Keene, 100 Southern Parkway, Rochester 18, N. Y.

STELLAFANE MEETING

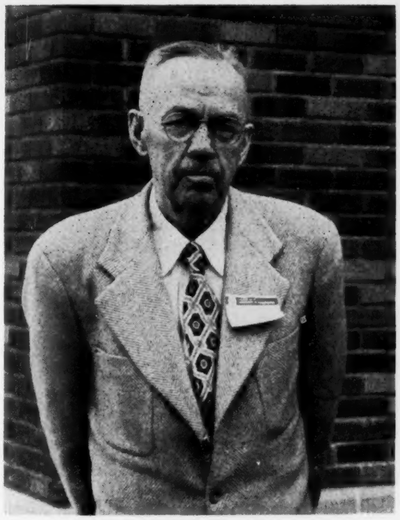
The 1960 Stellafane convention of amateur telescope makers is scheduled for Saturday, July 30th, on Breezy Hill in Springfield, Vermont. The meeting is being cosponsored by the Springfield Telescope Makers and the Amateur Telescope Makers of Boston.

Informal talks and a panel discussion will take place from 2 to 4 p.m. G. C. Camilli, Pittsfield, Massachusetts, will relate his experiences with two types of observatory buildings; Dr. Henry E. Paul, Norwich, New York, will talk on astrophotography for the amateur; and Ralph K. Dakin, Pittsford, New York, will discuss the correct alignment of Newtonian reflecting telescopes.

The evening program, from 7 to 9 o'clock, is to include northern Milky Way photographs by Edgar Everhart, Mansfield Center, Connecticut; a movie on solar research by Walter Semerau, Kenmore, New York; slides showing differences in star colors by William G. Cleaver, Mt. Carmel, Connecticut; Stellafane lore by John C. Pierce, Springfield, Vermont.

In addition to the usual awards for good telescope design and operation, a prize will be given the oldest instrument exhibited and another to the best-performing telescope over 15 years old.

Overnight camping is allowed in a nearby pasture. Hotel and room reservations may be made with E. Merryfield, Hartness House, Springfield, Vt. Further information about the meeting may be obtained from James W. Gagan, c/o Charles Hayden Planetarium, Museum of Science, Boston 14, Mass.



Carl P. Richards, always an enthusiastic conference delegate, as he appeared at the 1955 Seattle convention, where he received the Astronomical League award for his amateur work.

CARL P. RICHARDS DIES

One of the founders of the Astronomical League, Carl Price Richards, of Salem, Oregon, passed away on April 27th. He was 78 years of age. He received the league's annual award in 1955 for his leadership and accomplishments in the amateur astronomy field.

At the convention in Philadelphia in 1947, Mr. Richards was elected the first treasurer of the Astronomical League, and he later became vice-president. He was active in the development of the Northwest region, and a member of both amateur groups in Portland, Oregon.

The Salem amateur took pride in calling himself an "armchair astronomer," because he did most of his astronomical work with books and atlases instead of at the telescope. But he went on several expeditions to observe total solar eclipses, and was active in lecturing and demonstrating devices to amateur groups.

Geology was among his spare-time activities, and he was an enthusiastic mountain climber. Until his retirement about five years ago, Mr. Richards was a civil engineer with the Oregon state highway commission.

SOUTHWEST CONVENTION

The Children's Museum in Ft. Worth, Texas, will be the site of the Southwest regional meeting of the Astronomical League, on June 10th and 11th. Four groups are hosts: Ft. Worth Astronomical Society, Junior Astronomy Club of the Children's Museum, Texas Astronomical Society, and Astronomical Section of the Convair Recreation Society.

Registration begins at 3 p.m. Friday; the fee is $1.00 for adults, 50 cents for juniors. The chairman is Dr. H. C. Sehested, 3223 Westcliff Rd. W., Ft. Worth, Tex.

+++ AMATEUR BRIEFS +++

How good are you at unscrambling? The following astronomical terms are from the *Stellar Journal* of the Louisville (Kentucky) Junior Astronomical Society: LOGLA, OI, AREHT, RESCE, ALNU, ISNOJUR. (Answers are below.)

The Eastbay Astronomical Society of Oakland, California, apparently has enough doctors, lawyers, and Indian chiefs. It recently polled its membership to find out how many are in the "insurance game." What was the final count?

Case Institute of Technology in Cleveland, Ohio, will offer, for the first time, courses leading to a bachelor's degree in astronomy, starting this fall. Effective July 1st, Western Reserve University students will also be able to take Case astronomy courses, under a co-operative arrangement between the two institutions.

From the Grumman Astronomical Society's *Astro-Gas*: "The young son of a Cape Canaveral missile engineer was attending his first day at kindergarten. When the teacher announced that they were going to learn to count, the boy said proudly that he already knew how and proceeded to demonstrate: '10-9-8-7-6-5-4-3-2-1 — Nuts!' "

It's never too late. William Cleaver, a retired banker, has been named a research assistant at Yale University Observatory. He's an active member of the Astronomical Society of New Haven, Connecticut.

"Anyone who can see can be an amateur astronomer" is the inviting slogan printed each month in the Yakima (Washington) Amateur Astronomers' *Observer*.

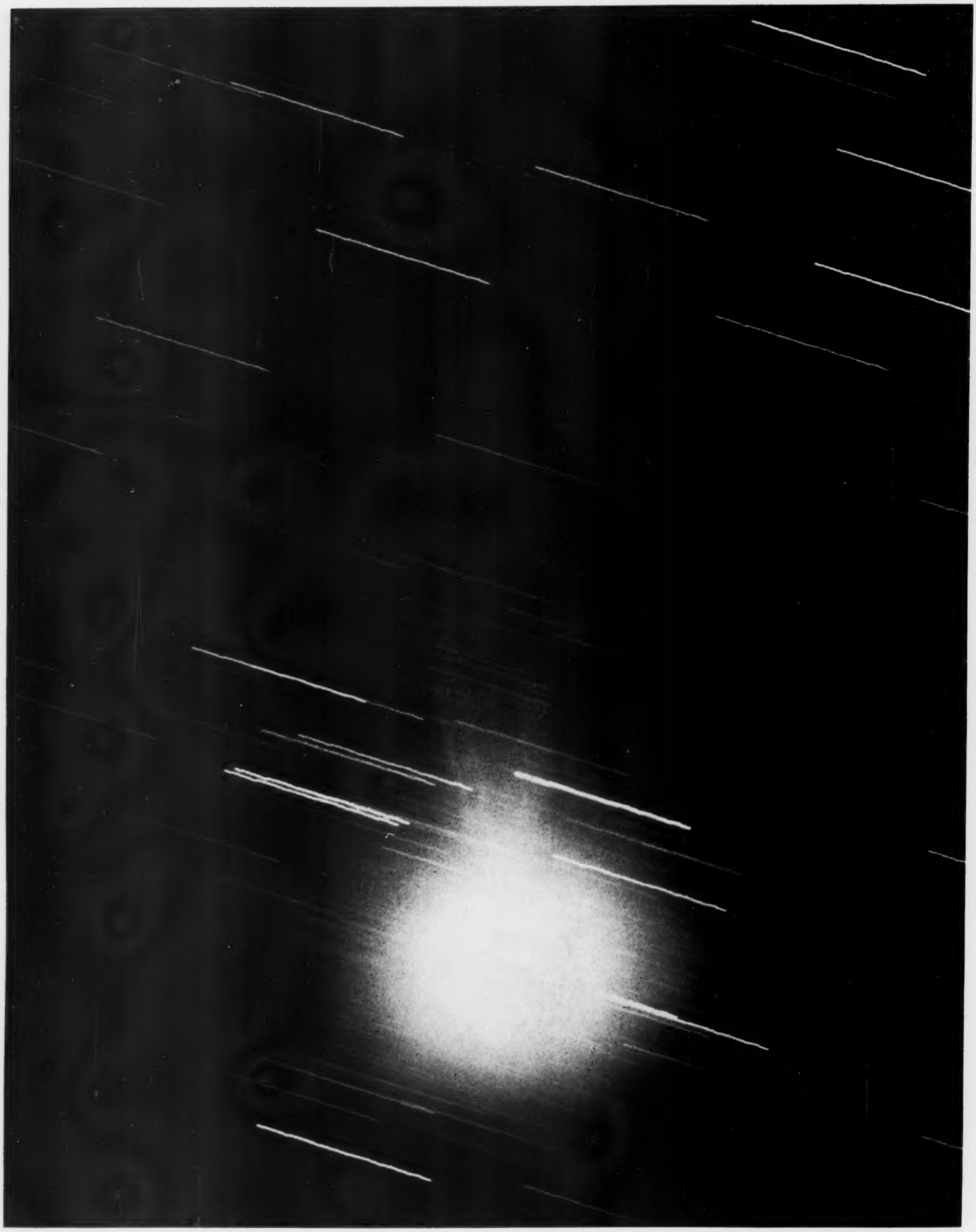
The relative merits of solar and sidereal clock drives for a telescope are considered in the April bulletin of the San Francisco (California) Amateur Astronomers. "A drive running at the solar rate will handle [visual] observations very nicely, and the cost of construction is considerably less. . . . If your interest is long-exposure photography, then it may well be worth the extra effort and cost to install a sidereal drive as it will make for less hand-guiding."

Twelve beautiful drawings of Messier objects are featured in the spring issue of *'Scope,* published by the Observation and Study Group of the Toronto Centre, Royal Astronomical Society of Canada. The striking sketches are part of a Messier catalogue the club is compiling.

On April 30th, Jack Borde, Dave Steinmetz, and Jerry Fritcke, of the Mt. Diablo (California) Astronomical Society spent the entire night observing artificial satellites and set some sort of a record for Moonwatching. By dawn, the trio had seen six different satellites, 12 different passes, and recorded 30 positions! The satellites observed were 1960β1, 1960β2, 1959η2, 1959α2, 1959ι1, and 1960γ2.

Quiz answers: Algol, Io, Earth, Ceres, Luna, Juniors.

H. M. C.



Elizabeth Roemer took this photograph of Comet Burnham 1959k on April 25, 1960, near the time of its closest approach to the earth, at a distance of about 20,000,000 miles. The comet was then of the 4th magnitude, slightly fainter than early predictions had suggested. This is a 15-minute exposure with the 40-inch reflector of the U. S. Naval Observatory's Arizona station, near Flagstaff. A fast blue-sensitive emulsion was used, Eastman 103a-O. On this enlargement, each millimeter corresponds to 9½ seconds of arc. The comet was in Cygnus, traveling northward at about one-third of a degree per hour. To obtain an unblurred image, Dr. Roemer guided the telescope on the comet, letting the stars trail during the exposure, the trail lengths indicating the amount of the comet's motion. Note the delicate columnar structure of the tail, which was surprisingly faint for a comet of this brightness. Official U. S. Navy photograph.

OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

News of Comet 1959k

THE very faint moving patch of nebulosity discovered by Robert Burnham, Jr., at Lowell Observatory last December 30th has become the brightest comet in several years. Nearest to the sun on March 20, 1960, Comet Burnham on its outward course passed close to the earth in April, providing a fine sight in the northern sky for binoculars and small telescopes.

The long, faint tail of Burnham's comet could be traced to a length of 7.4 degrees on the original of this photograph by Alan McClure, Los Angeles, California, on April 22nd, from 11:00 to 11:20 Universal time. His camera with a Zeiss $5\frac{1}{2}$-inch lens, f/5.0, was set up on Mt. Pinos, 8,300 feet above sea level.

As told in an earlier article (page 292 of the March issue) the comet was nearly in line with the sun in March, and was for a time unobservable in the solar glare. One of the earliest recoveries was by the New Zealand amateur A. F. Jones, at Timaru. On March 26th he saw it as magnitude 6.6, and by April 8th the comet had brightened to 6.0. On two dates during that interval, he recorded the visible tail as 10 minutes of arc long.

One of the most intensive observing series by an American amateur was that of Alan McClure, Los Angeles, California. From his visual examination of the comet on April 7th and 8th in 12×70 binoculars, he found it of magnitude 6.2, resembling a small unresolved globular cluster, and without a tail. On the morning of the 8th, he obtained a 17-minute photographic exposure in blue light with a 7-inch f/7.0 Fecker lens. This showed a very faint tail about 3° long.

At that time the comet was in Aquarius, and beginning to move rapidly northward across the morning sky. Full moon came on the 11th, so for some time bright nights interrupted watch on the comet. A photograph taken April 17th, by Elizabeth Roemer with the U. S. Naval Observatory's 40-inch reflector in Arizona, showed much delicate fibrous structure in the tail, even though her 10-minute exposure was badly fogged by moonlight and haze.

According to Dr. Roemer's estimates of the magnitude of the comet, as seen extrafocally in binoculars, it was brightening steadily. She reports the following values: April 4, 7.3; 17, 5.9 or 6.0; 21, 4.5; and 25, 4.3 or 4.4. On that last date, she saw the head of the comet as a well-condensed coma about 15 minutes of arc in diameter, but without any starlike nucleus.

The striking peculiarity of Comet 1959k during most of April was the unusual faintness of its tail, which was much less conspicuous than for most other comets that become so bright. Late in the month, however, the tail was becoming more apparent.

The properties of the tail were well shown in a photograph made the morning of April 26th at Organ Pass, New Mexico, by John Priser, who took a 60-second exposure with the f/1 Baker-Nunn camera

of the Smithsonian Observatory's satellite tracking station. The tail was fully 6° in extent on the original negative, forming a faint, very narrow fan. About two diameters of the coma outward along the tail, there were several slight kinks.

By the end of April, Comet Burnham was a northern circumpolar object, hence observable all night, and many amateurs took it under watch. W. E. Iversen, Stamford, Connecticut, noted it as plainly visible in binoculars, near the head of Draco, on April 28th. Its motion was detectable during his three-hour scrutiny. This was the fifth night on which he had viewed the comet. According to Mr. McClure, the magnitude was 4.8 on that date, and the object had less tail than previously.

Also on April 28th, Edgar Everhart, Mansfield Center, Connecticut, obtained a 25-minute exposure with a Petzval lens of 20-inch focus, used with a field flattener. His picture showed a very narrow straight tail about 4° long.

The following night, Comet Burnham was accidentally picked up by Bruce Gelin, Wilmington, Delaware, as he was scanning the vicinity of Zeta Ursae Minoris with his 2.4-inch refractor. At the time he did not know the identity of the "strange fuzzy object."

At Philadelphia, Pennsylvania, G. M. Foley took successful photographs on April 30th with a Biotar 58-mm. f/2 lens on 35-mm. Plus-X film. An exposure of 30 seconds gave strong images.

The latest available information about Comet Burnham is from observations by Dr. Roemer on May 1st. A 20-minute exposure with the 40-inch reflector showed that the tail was very much fainter, and only 40′ long. The visual magnitude was 5.4, representing a marked fading since April 29th.

D. Meisel, who is director of the comets section of the Association of Lunar and Planetary Observers, is collecting amateur reports of this comet for a comprehensive discussion. He mentions that the maximum observed extent of the tail was on April 22nd, when it amounted to 7°.4 on a negative taken by Mr. McClure (see picture on page 479). Observing reports for Mr. Meisel should be sent to him at 800 Eighth St., Fairmont, W. Va.

The spectacular show presented by Comet Burnham 1959k is now over, and it is fading very rapidly as its distances from the earth and the sun are increasing. No ephemeris later than that on page 292 of the March issue is available; it extends to May 26th, when the comet was to be an inconspicuous telescopic object in the constellation Leo Minor.

DRAWING THE MOON AND PLANETS

Many helpful hints for the amateur who wishes to make pencil drawings of lunar or planetary surface features are given by William K. Hartmann in the January-February issue of the *Strolling Astronomer.*

In sketching a lunar crater, for example, Mr. Hartmann recommends first inserting the major features from observation with relatively low magnifications. Smudging is useful for obtaining uniform shadings. The subject is then viewed with higher powers, and smaller details are added until the observer is satisfied that all that can be certainly seen has been included.

Every drawing should be accompanied by descriptive notes to aid its interpretation. For the beginner, copying lunar photographs helps develop drawing techniques, and sketching the naked-eye appearance of the moon is useful practice for planetary observers.

The issue in which Mr. Hartmann's article appeared can be obtained at 70 cents per copy from its editor, Walter H. Haas, Pan American College Observatory, Edinburg, Tex.

SUNSPOT NUMBERS

The following American sunspot numbers for March have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

March 1, 66; **2,** 63; **3,** 57; **4,** 81; **5,** 87; **6,** 83; **7,** 103; **8,** 119; **9,** 107; **10,** 92; **11,** 94; **12,** 65; **13,** 57; **14,** 66; **15,** 82; **16,** 88; **17,** 92; **18,** 94; **19,** 93; **20,** 103; **21,** 100; **22,** 133; **23,** 121; **24,** 119; **25,** 128; **26,** 53; **27,** 88; **28,** 118; **29,** 115; **30,** 121; **31,** 97. Mean for March, 93.0.

Below are provisional mean relative sunspot numbers for April by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

April 1, 140; **2,** 143; **3,** 152; **4,** 162; **5,** 156; **6,** 143; **7,** 123; **8,** 112; **9,** 98; **10,** 103; **11,** 107; **12,** 136; **13,** 128; **14,** 133; **15,** 162; **16,** 159; **17,** 110; **18,** 116; **19,** 128; **20,** 116; **21,** 123; **22,** 108; **23,** 99; **24,** 96; **25,** 95; **26,** 96; **27,** 86; **28,** 99; **29,** 82; **30,** 100. Mean for April, 120.4.

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S1435	6 x 30 IF	395	"Zeiss"	16.75
S1438	7 x 35 CF	341	"Zeiss"	20.75
S1437	7 x 35 IF	341	"Zeiss"	17.95
S1771	7 x 35 CF	341	American	23.50
S1439	7 x 35 CF	578	American*	35.00
S2191	7 x 50 CF	530	American**	42.50
S1106	7 x 50 CF	372	"Zeiss"	24.95
S-961	7 x 50 IF	372	"Zeiss"	22.50
S1503	7 x 50 CF	372	American	32.50
S1443	8 x 30 CF	393	"Zeiss"	21.00
S1229	8 x 30 IF	393	"Zeiss"	18.25
S1108	10 x 50 IF	275	"Zeiss"	26.75
S1442	20 x 50 CF	183	"Zeiss"	33.75
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Cat. No.	S1303	7 x 50	14.75 ppd.
Cat. No.	S1579	16 x 50	17.50 ppd.
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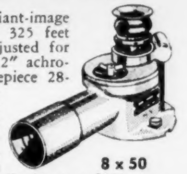

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S1507	Pyrex	6"	60"	25.00
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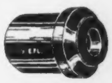

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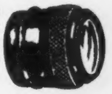

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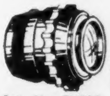

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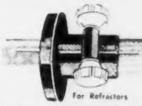

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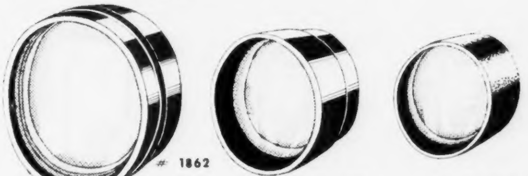

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S1158	(3⅛")	(19½")	28.00
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S1092	(3¼")	(26")	28.00
S1093	(3¼")	(28")	28.00
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S-955	(3¼")	(34½")	28.00

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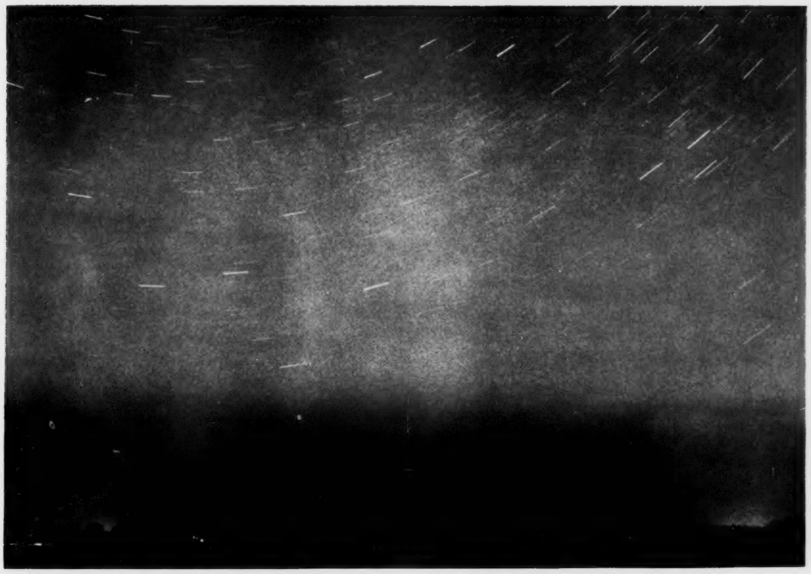

Wayne L. Norton, Ridgeville, Indiana, photographed the April 23rd aurora with a 75-mm. f/3.5 lens, the exposure time being about seven minutes. The constellation Cassiopeia is left of center.

APRIL AURORAS

WIDESPREAD aurora activity occurred late in April, according to reports sent to SKY AND TELESCOPE. On Saturday evening, April 23rd, an evening display was seen by Jack K. Vorrenter at Lakemont, New York; Lewis Dewart, Sunbury, Pennsylvania; LaVerle Berry, Perrysville, Ohio; Donn Cuson, Grand Rapids, Michigan; Wayne L. Norton, Ridgeville, Indiana; Al Stewart, Elmhurst, Illinois; George W. Rippen, Madison, Wisconsin; and Josef R. Otoupalik, Greeley, Colorado.

Four evenings later, northern lights were again seen at Lakemont, Sunbury (by William J. Nagle), Ridgeville, and Elmhurst. They were photographed by Carl Kwadrat at Duquesne, Pennsylvania, 12 miles east of Pittsburgh, and seen at Appleton, Wisconsin, by David Geenen, John Roegner, and Thomas Kemen, as a "brilliant display."

Also, from as far west as Pinehurst, Idaho, auroral phenomena took place. In one night's observing Claire C. Cahill saw a pale green and yellow aurora, which later showed green and red flashes and draperies, a brilliant reddish fireball between the Big Dipper and Cassiopeia, and Comet Burnham 1959k.

Again on April 28th, Mr. Vorrenter saw auroral activity from the shores of New York's Seneca Lake.

DEEP-SKY WONDERS

ONE of the most interesting types of telescope to be developed lately is the official Moonwatch apogee refractor. Designed for observing faint artificial satellites, it combines a standard M-17 ocular and roof-prism assembly with a 5-inch objective of about 20 inches focus. The field is $2\frac{1}{2}°$ and the power 20. It provides a revelation for observers of clusters and nebulae.

On a sharp, unseasonably cold night in late March, when two feet of snow blockaded my observing site, an apogee telescope was set up in the cleared area around my car. I first turned it on Coma Berenices. The night was very clear, for to the unaided eye this cluster did not have its usually hazy shimmer. Instead, each star stood out clearly, and I needed a second or two to be sure that it really was Coma.

In the telescope the images were sharp and small, and the galaxy NGC 4565 was noticed without effort, just off the luminous V of stars. The object seemed bright, about magnitude 8.5, though the Skalnate Pleso *Atlas Catalogue* gives 10.2. It looked like a blazing little needle in the sky, and even fast sweeping picked it up readily. Held in the field, this galaxy seemed all of 15′ long by perhaps 45″ wide, fairly uniform along its entire length.

The fine edge-on galaxy NGC 4565 was discovered by Sir William Herschel, and listed by him as No. 24 of his class V (very large nebulae). Mount Wilson and Palomar Observatories photograph.

Photographs reveal NGC 4565 to be a beautiful edgewise spiral, and while the apogee telescope could not show the dark band of dust that cuts the nucleus through the middle, a 10-inch reflector will. The 1950 position is $12^h\ 33^m.9$, $+26°\ 16'$.

Then the hand-held telescope slipped, the field sliding rapidly about 10°. But I was able to see a bright globular cluster as it whipped by. A little cautious hunting recovered the object, with a curious snake of bright stars above it and a wide pair below, identifying the cluster as M53 (NGC 5024) without even consulting a chart. It was probably the most dramatic view of this globular I have ever had, for it seemingly hung between the earth and the starry background. Much brighter at the center, M53 too appeared more luminous than its catalogue magnitude of 7.6. Those who depend on setting circles will find this cluster at $13^h\ 10^m.5$, $+18°\ 26'$.

N. T. Bobrovnikoff has shown that the estimated magnitude of a comet depends greatly on the telescope used, the comet seeming brighter in smaller instruments. This appears to be true, too, for globular clusters and galaxies, at least to some extent. Several objects near M53 – M3, NGC 4559, and NGC 4656 – looked much brighter in the apogee telescope than expected.

The night must have been an unusually fine one. The naked-eye limit for the North Polar Sequence stars was 7.4, but I made no test there with the telescope. About midnight I saw a small amount of zodiacal light on the western horizon; at the same time the Beehive cluster to the naked eye looked like M13 in a 3-inch telescope. The gegenschein was found after a minute of searching, and a zodiacal band clearly ran from the western horizon to it. But even with averted vision it was not possible to trace the band from there to the eastern horizon.

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BOOKS AND THE SKY

INTRODUCTION TO THE MECHANICS OF THE SOLAR SYSTEM

Rudolf Kurth. Pergamon Press, New York, 1959. 177 pages. $6.50.

WITH the renewed interest over the last three years in dynamical astronomy, several books on celestial mechanics have appeared. Most of these are rehashes of standard works of the past, with more or less insight into methods initiated by Lagrange, Laplace, Gauss, Hamilton, Jacobi, and Poincaré. Some contain a chapter or so dealing with more modern material, such as the relativistic advance of Mercury's perihelion, but all tend to be presentations of classical material in a classical manner with classical notations.

In Rudolf Kurth's new textbook we discover a fresh and unconventional approach to the problems of celestial mechanics. "Like Socrates," as the author says in the preface, he "dislikes long speeches — and long formulae; and the formulae of celestial mechanics can indeed be very long." His avowed intent is to promote the understanding of fundamental principles and methods. He is not concerned with "ready-made recipes" but with a "methodical approach."

The book has four chapters. The first is called "The Kinematics of a Single Planet." Beginning with the axiomatic treatment that he uses through most of the text, Kurth derives the relation between the synodic and sidereal periods that is found in all elementary textbooks in astronomy, but in a rigorous manner. He indicates the assumptions and approximations that are made and the order to which the expressions are valid. He shows how Kepler's laws of planetary motion may be derived from the observations and then how, knowing the elliptic elements, the orbital motion may be determined. Kepler's equation is obtained and solved by a series of successive approximations. Convergence of the method used is proved by the methods of analysis. At this point vectorial notation is introduced, to be used throughout the remainder of the book. The author shows theoretically how an orbit may be determined from three observations and later improved by comparison with additional observations.

Chapter II, "The Dynamics of a Single Planet," begins with a discussion of force and mass, assuming that the reader has never seen the axiomatic treatment of this subject found in physics books. The differential equations of motion are solved analytically, as well as by the methods of Laplace and Gauss for orbit determination purposes.

The next section, "The Dynamics of the Planetary System," is the heart of this work, for it deals with the general integrals of the equations of motion and perturbation theory. Perturbations in the co-ordinates and in the elements are developed. In the former there is a brief discussion of long-period and secular terms, as well as an indication of the methods employed by Adams and Leverrier in determining the elements of Neptune from the observed perturbations of Uranus. In the variation of elements, the methods of Lagrange and Poisson are employed.

Stability of the solar system is touched upon, and a simple derivation of some lunar inequalities is given. The secular advance of Mercury's perihelion is obtained by assuming an acceleration, additional to the Newtonian, which is inversely proportional to the distance and the square of the velocity of light. This gives a term equivalent to that obtained in relativity theory. Finally, there is a brief discussion of the restricted problem of three bodies.

In Chapter IV, "The Planets and the Moon as Rigid Bodies," Kurth derives the motion of pericenter and nodes about a rotationally symmetric planet, the precession and nutation of the earth, and gives a brief treatment of the moon's rotation.

This book assumes a knowledge of advanced calculus, some matrix algebra and

vector analysis, and is on the senior or first-year graduate level. Except for a few places where diagrams would have greatly improved the clarity of presentation, and for a very few sentences translated awkwardly from the German, the material is lucidly presented.

There are few typographical errors – page headings for Chapter I erroneously use the word kinetics instead of kinematics; the power 2 is missing in equation (1) on page 48; the draconitic period is confused with the saros on page 128; incorrect references to equations are occasionally given. One great inconvenience is the system of references to equations. A reference such as III § 6.2(5) generally requires going through the table of contents, which does not contain the subsection number, only its title. (Subsections contain number but not title.)

This book can be recommended highly for giving the feel and some of the spirit of celestial mechanics. It can profitably be used as collateral reading in a first course. Some ideas presented are open to serious criticism, in particular the author's feeling that canonical methods are useless except in statistical cases. The fruitfulness of such an approach is attested by its successful application to many classical and current problems. A recent issue of the *Astronomical Journal*, for example, has three papers on the motion of artificial satellites in which canonical variables give elegant and practical solutions.

The author's insistence on first-order simplicity may mislead many students into thinking that actual planetary or satellite problems can be solved without the long formulae of celestial mechanics. Unfortunately, this is not so.

MORRIS S. DAVIS
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KEPLER

Max Caspar. Abelard-Schuman, New York, 1959. 401 pages. $7.50.

MAX CASPAR'S long biography of Johannes Kepler, translated from the German by C. Doris Hellman, is a compassionate and thorough survey of the life of the great 17th-century astronomer. Starting with an excellent introductory account of the religious turmoil of the period, the book traces the life of Kepler from his childhood in Weilderstadt to his death at Regensburg in 1630.

Intricately detailed and always sympathetic to the central character, this is probably the most authentic picture of Kepler yet drawn. The author's scholarship and confessed love for the astronomer result in an extremely penetrating yet readable history of a genius tormented by the conflicts of his time.

Following the introduction, the book is divided into five chronologically arranged sections and a concluding comment. "Childhood and Youth 1571-1594" is concerned with the development of the young Kepler as he prepares for the ministry. A verbal portrait of his family and the faculty at his university gives the reader a comprehension of some of the forces that were to drive the man relentlessly toward his goal, despite ill health, family upheaval, church disputes, and wars.

The next two sections, "District Mathematician and Teacher in Graz 1594-1600" and "Imperial Mathematician in Prague 1600-1612," trace the triumphs and failures of Kepler's early manhood, through the publication of the first two of his three immortal laws of planetary motion. His tumultuous association with Tycho Brahe, his unending financial difficulties,

and his troubles with authority, although important factors in the development of his character, are seen to have little or no effect upon his keen intellect and scientific curiosity.

"District Mathematician in Linz 1612-1626" pictures one of the darkest eras of Kepler's life and one of his greatest triumphs. The pervading misery of his mother's trial for witchcraft is vividly portrayed as Caspar describes the idiocy of the proceedings, and the tribulations they brought to Kepler. The publication of his third or harmonic law and the studies in music that preceded it are equally well handled.

The last four years of an ill and tired old man are depicted in the fifth section. Although still active in mind, Kepler was failing in health. Denied the sacraments of his church, he clung steadfastly to his faith, and finally was buried in the churchyard in front of Peter's Gate in Regensburg.

Professor Caspar points out that, because of impending invasion, the townspeople plowed up the cemetery to make fortifications, shortly after Kepler was laid to rest. "Thus, but a few years after his death, the resting place of his bones was no longer known. Tycho Brahe's grave is in the Tyn church in Prague, Galileo is buried in the venerable church of Sante Croce in Florence, Newton rests among the great dead in Westminster Abbey. Veneration for genius erected these worthy monuments. But no tombstone covers the place where the no less gifted Kepler was interred. It is as though the fate, which in life gave him no peace, continued to pursue him even after death."

Thus Caspar pictures the genius fighting a losing battle, but still persevering to make far-reaching scientific contributions. The last part of the book is a final comment upon the life and works of the astronomer during his 59 troubled years.

The author effectively dispels the erroneous notion that Kepler's astrological activity removes him from the realm of the true scientist. Kepler did not believe in his own astrological predictions, but published them only for the needed income they produced. This is clearly shown in many places in his writings, where the astronomer urges his patrons to disregard astrology when making important decisions.

The fact that Kepler delved into the false sciences is further excused by the temper of the times. As Caspar says: "One who looks about in that departed era of writing and printing is astonished at the flood of astrological, alchemical, magical, cabbalistic, theosophic, mock mystic and pseudoprophetic writings which held the intellects in a spell."

This volume is unfortunately printed in small type that is rather difficult to read. Undoubtedly, the length of the material forced a choice between an excessively bulky book and diminutive print. Shortening the text would have seriously weakened the completeness of description and documentation that are among its finest features.

Sir Isaac Newton once said that if he saw farther than other men, it was because he stood on the shoulders of giants. Without doubt, one of those giants was Johannes Kepler, and his biography by Max Caspar befits his stature.

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ASTROPHYSIQUE GENERALE

J. C. Pecker and **E. Schatzman.** Masson et Cie., Paris, 1959. 756 pages. 130 NF.

FRENCH TEXTS on astrophysics at the college level are few and far between. The previous work of similar scope, *Astrophysique* by J. Bosler (1928), was primarily descriptive. It covered much the same ground and had about the same elementary level as the standard American textbook of Russell, Dugan, and Stewart.

In *Astrophysique Générale,* two well-known French astronomers have joined forces to write a comprehensive, up-to-date treatise on modern astrophysics for the student with a good background in physics and mathematics (about two or

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BOOKS FOR THE AMATEUR

Larousse Encyclopedia of Astronomy. By Lucien Rudaux and G. de Vaucouleurs. The long-awaited English translation of this monumental volume — one of the most complete and best-illustrated compendiums of astronomy ever offered in one book. Many full color renditions. Full-page size is 8 by 11⅛ inches. 506 pages, 818 illustrations. **$12.50**

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SKY PUBLISHING CORPORATION Harvard Observatory, Cambridge 38, Massachusetts

three years at the college level). Although the book is based on the authors' lectures to astronomy undergraduates at Clermont-Ferrand and Paris universities, much material has been added and the treatment so developed that some parts will be most valuable to the graduate student. The reviewer is not aware of a treatise of similar scope and level in the English language. It is no small feat for two authors to be able to cover competently such a wide range of topics.

The book has five parts: basic physical notions (100 pages), instruments and techniques (135), stellar physics (120), stellar systems (155), sun and solar system (105). There is a useful notation index (four pages) and a good name and subject index (15). Each chapter is followed by a substantial bibliography with brief comments. There are 396 illustrations, mainly graphs and sketches, with rather few photographs. There is a total of 303 tables of numerical data, a remarkable compilation of valuable information.

The first part is a compact but well-organized summary of fundamental ideas in statistics, classical mechanics, hydrodynamics, spectroscopy, and the theory of energy exchanges and statistical equilibrium between radiation and matter. It is well up to date (including, for example, sections on magnetohydrodynamics and on synchrotron radiation), perhaps occasionally at the expense of classical subjects of practical importance to the astronomy student (such as the method of least squares, also molecular spectra).

Part 2 is primarily a digest of standard French texts on classical instruments and techniques of observation, discussing such subjects as atmospheric absorption, photometry, spectroscopy and spectrophotometry, optical telescopes, receivers, accessories, mountings, and domes. Here the treatment is elementary and essentially descriptive. Despite some mention of radio telescopes and interferometers, birefringent filters and rockets, these chapters show the French astronomical instrumentation of a decade or two ago rather than of the present. A serious effort of revision and updating is needed here.

Part 3 forms the core of the book, covering the fields of special competence of the authors: stellar atmospheres (Pecker) and stellar interiors (Schatzman). This is reflected in the development accorded to many details. After a survey of the empirical classification of stellar spectra, their interpretation by the physical theory of stellar atmospheres is worked out. The radiation transfer problem, the computation of model atmospheres in gray and nongray cases (with one of the few numerical examples in the book), the formation of spectral lines and line profiles (including rotation, turbulence effects) are clearly explained. Departures from local thermodynamic equilibrium, convection zones, coherent and incoherent scattering are then discussed, and applications made to the determination of temperatures and abundances (curve of growth). An appendix gives additional details and numerical data useful in the theory of stellar atmospheres.

This is followed by a descriptive chapter on stellar distances, the H-R diagram, and the mass-luminosity relation. The section on double stars (visual, spectroscopic, photometric) and stellar masses is fairly routine, but adequate, except perhaps for the discussion of eclipsing binaries, which is too succinct and lacks a numerical example (such omissions weaken many other sections of the book).

Variable stars are considered at some length, with an outline of the theory of stellar pulsations, including shock waves (Cepheids). Types of variables are illustrated with typical light curves. The one-page discussion of supernovae is much too brief, and some statements there are not even correct.

The chapter on the internal structure of the stars (45 pages) contains an excellent presentation of the classical and nuclear physics involved, including fairly detailed treatments of the nuclear cross sections and thermonuclear reactions of interest in astrophysics. The principles of the computation of stellar models are described, followed by details of some special solar and stellar models, with ap-

plications to evolution problems. The white dwarfs are touched upon, while hydrodynamic and stability problems are developed at some length.

Part 4 opens with a descriptive account of stellar motions and distribution, with remarks on clusters and associations, leading to the determination of the direction of the galactic center and separating the various stellar subsystems. The derivation of space densities from star counts is accorded only two pages, resulting perhaps from a strong reaction against the emphasis placed on the subject by astronomers of the previous generation.

Stellar kinematics and dynamics are then adequately treated in two chapters (30 pages), including both classical and modern problems, such as the stability and structure of star clusters and associations, and the mapping of H-I arms through the application of the theory of differential rotation of the galaxy to 21-centimeter observations.

The following section is a return to problems of stellar evolution, incorporating the evidence from galactic clusters, the luminosity function, and miscellaneous other data (stellar rotation, abnormal abundances). Questions related to element formation and abundances (novae, supernovae) are not explored, however.

The important problems of interstellar matter are presented in a chapter of 45 pages, which begins with a brief survey of statistical methods (Wolf diagrams, fluctuations in galaxy counts and in sky brightness). The observations and theory of interstellar absorption, scattering and polarization, and the physics of emission nebulosities are then discussed in more detail, including brief sections on continuous and 21-cm. radio emission.

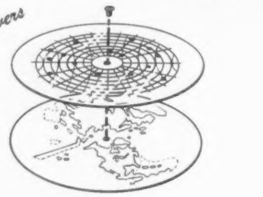
A final chapter reviews classical and current ideas on galaxies and cosmology. Here the treatment of the empirical data is rather sketchy and occasionally inaccurate. As far as it goes, the brief survey of cosmologies is better, but fails even to mention the steady-state theory.

Part 5, reflecting happily the special interest of one of the authors, concerns the sun: energy distribution, limb darkening, solar models, chromosphere and corona, magnetic and hydromagnetic effects. There is a good chapter on sunspots and solar activity and another on solar-terrestrial relationships.

By contrast, the final section, on planets and minor bodies of the solar system, is disappointing. A few points, such as the theory of surface temperatures, escape of atmospheres, internal structure, are briefly outlined; but the discussion of individual objects is almost nonexistent (Venus, six lines; Mars, 10; zodiacal light, 12). Some will think that in this space age the neglect is unfortunate.

All in all, *Astrophysique Générale* is a major and successful effort to provide students with a good grounding in most of the fields of astrophysics active during the past two decades. One hesitates to criticize such a courageous undertaking. However, if a general appraisal must be made, it is that the book reflects a little too clearly, if understandably, the fields of special interest and competence of the authors, at the expense of other important subjects where the compilation was obviously hasty and uncritical. There should therefore be a thorough revision and rewriting of several chapters, especially if the book were to be translated into other languages.

It is, of course, almost impossible to achieve perfection in the first edition of a book of this size and scope, so it would be pointless to record here the several dozens of minor errors and misprints



noticed in a first reading. Also, captions of figures and references are often incomplete, sometimes incorrectly given, and require checking.

As the book is clearly destined to run through several editions and to become a standard text, the authors should have ample opportunity to polish up this valuable work, for which they certainly deserve the congratulations and gratitude of teachers and students.

G. DE VAUCOULEURS
Harvard Observatory

NEW BOOKS RECEIVED

ASTRONOMISCH-CHRONOLOGISCHE TAFELN FUR SONNE, MOND UND PLANETEN, *Paul Ahnert,* 1960, *Johann Ambrosius Barth,* Salomonstr. 18B, Leipzig C1, East Germany. 93 pages. DM 10.20, paper bound.

Astronomical and Chronological Tables for Sun, Moon, and Planets furnishes the means of calculating the approximate positions of solar system bodies for any selected date, using only simple arithmetic. These tables begin with 3001 B.C. for the sun and moon, and with 1501 B.C. for the planets Mercury through Saturn, extending to A.D. 2499 in each case.

Dr. Ahnert's publication can also be used for finding the dates of planetary phenomena, and of full and new moon. In addition, the approximate circumstances of eclipses can be calculated with its aid. The 42-page explanation of the use of the tables is in German.

THE OSCILLATING UNIVERSE, *Ernst J. Opik,* 1960, *Mentor Books.* 144 pages. 50 cents, paper bound.

Despite its title, this book is mainly an up-to-date account of the nature of solar system bodies. Popularly written, it contains the views of a professional astronomer whose special field is the planets and meteors.

PROPERTIES OF DOUBLE STARS, *Leendert Binnendijk,* 1960, *University of Pennsylvania Press.* 349 pages. $12.50.

A staff member of Flower and Cook Observatory presents a survey of the methods of modern double star astronomy. Successive sections deal with photographic measurements employing long-focus refractors, visual double stars, spectroscopic binaries, and eclipsing variables. The emphasis throughout is on the mathematical bases of observing techniques and orbit determinations.

AL-BIRUNI ON TRANSITS, *al-Biruni,* 1959, *American University of Beirut.* 201 pages. 6.25 Lebanese pounds.

This is a translation into English of a work on spherical astronomy and planetary motions, written by the Arab astronomer al-Biruni, who died in the year 1048. For historians of astronomy, it contains much valuable source material bearing on the problem of the transmission of astronomical ideas in the Near East. The translators are M. Saffouri and A. Ifram, and E. S. Kennedy has provided a commentary.

The book can be ordered at $2.00 per copy from Khayat's Bookstore, 23-24 Rue Bliss, Beirut, Lebanon.

THE MOON, *Franklyn M. Branley,* 1960, *Crowell.* 114 pages. $3.50.

Earth's natural satellite is described for teen-agers in this well-illustrated book.

GLEANINGS FOR ATM's

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MY GREGORY-MAKSUTOV is a 6-inch f/23 instrument, yet compact and portable for such a powerful telescope. Everything but the tripod fits into a wooden carrying case and weighs a total of 69 pounds. The spherical mirror was fairly simple to make, as no parabolizing was necessary. This f/23 design gives excellent results with no aspherizing, although that extra figuring would be desirable for an f/15 instrument.

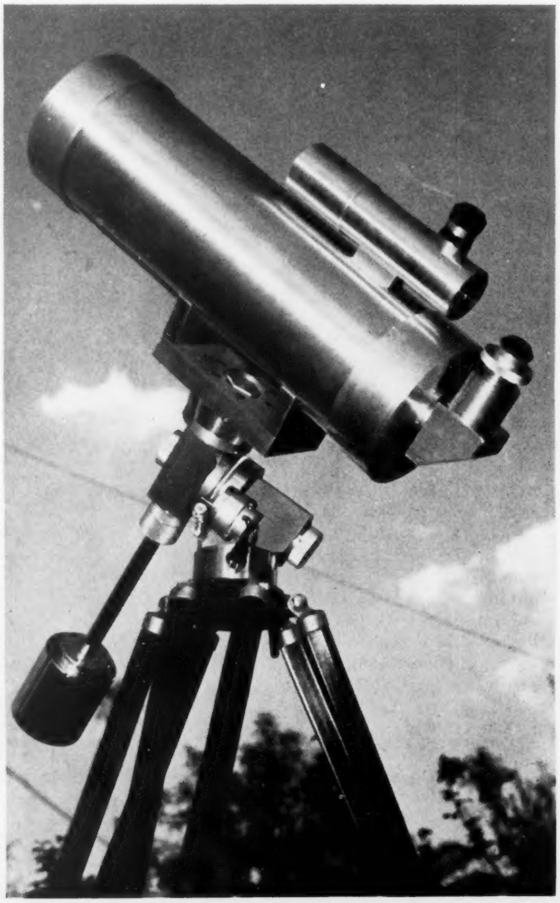
Making the corrector lens is considerably more difficult. It is no job for anyone who might be in a hurry to get a Maksutov finished for the next apparition of Mars and has yet to start grinding. The better part of a year and a half of spare time went into constructing the testing equipment and the corrector. The three instruments in the picture opposite are a radius spherometer, the jig for determining central thickness, and a jig for controlling wedge and concentricity of the lens.

It is convenient for all three of these instruments to have their own dial indicators, especially for the later stages of grinding the last surface. Here the lens is approaching its final thickness, so it is necessary to stop every few minutes and check both the radius and wedge to be sure they are within the design tolerance.

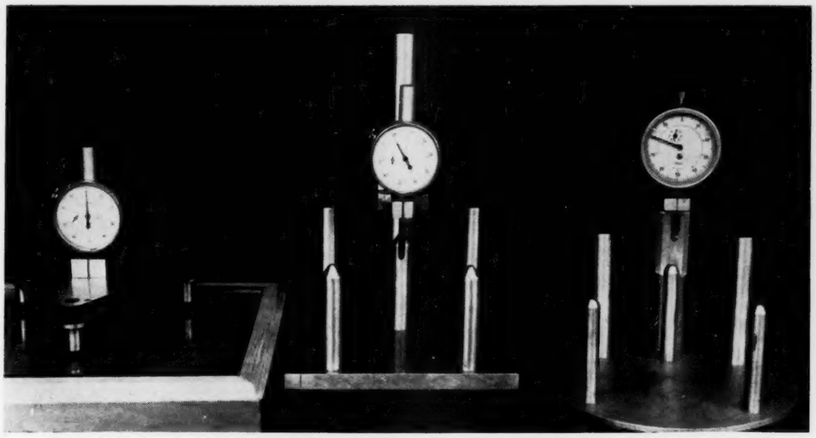
The corrector was made from an Edmund square glass blank. Grinding was done on a vertical spindle, a lead lap being used for roughing, a cast-iron one for smoothing, and tiles cemented on the cast iron for fine grinding. All polishing was performed with a Draper machine, while the optical figures were checked with a beam-splitter light source and a combination Foucault-Ronchi tester.

Since the image from the first surface (the concave one) is about four times as bright as the one from the convex surface when testing through the lens, checking for zones and smoothness would have been a problem without the suggestions of A. S. Leonard in Maksutov Club *Circular* 38. In Dr. Leonard's method, the lens is deliberately left with a 0.006" wedge between the surfaces, the central thickness a bit too great, and the front surface concentric with the rear. The first side is given a good polish and made spherical; then the rear surface is polished and tested through the first.

By arranging the lens properly on its



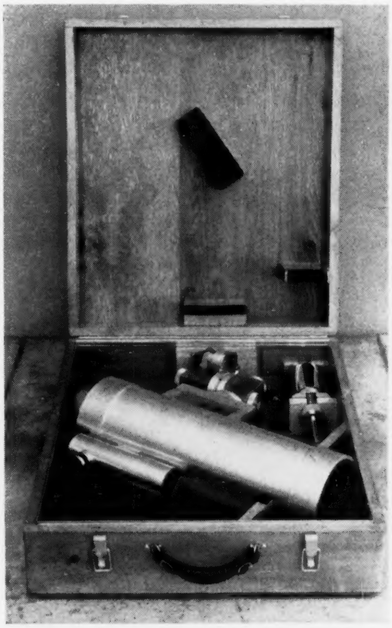
Gordon Konstanzer's 6-inch telescope has an extremely rigid mounting, with thrust bearings 3½ inches in diameter at the top ends of both axes. When he first observed, Mr. Konstanzer spent more time searching for objects than looking at them, so he added the finder, which has a 7-x-50-binocular objective and a 6-x-30-binocular eyepiece. The Linhof heavy-duty camera tripod was not steady enough in its original form, so aluminum struts were added, joining the top ends of the lower legs. Observing stability was greatly improved. All photographs with this article are by the author.



At the left, resting on a glass plate for setting it to zero, is the radius-measuring spherometer. The middle device was used for checking the center thickness of the lens, and the third for testing the corrector's edge.

test stand, the image from the first surface is made to fall behind the knife-edge, allowing the worker to test the rear side without interference. After this surface is finished, the front one is reground to the design radius, the wedge removed, and the central thickness reduced to its proper value. One must produce a total of three optical surfaces on the correcting lens to employ this technique, but the extra work is not difficult. In fact, it is good experience, and in my case enabled me to obtain an excellent figure on the convex surface. Of course, great care must be taken so that the finished rear side does not get scratched while the front one is being worked.

Since the corrector had to remain in a single position during the testing of the convex surface, the lens and the lap were rotated at different speeds on the Draper polishing machine to avoid astigmatism, which might have been masked by the fixed lens position.



The telescope's carrying case is 26 by 22 inches in area, eight inches high, weighing 69 pounds when packed.

The telescope tube was completely machined in one lathe setting, thereby assuring perfect alignment of the corrector in its cell. The mirror is in a conventional cell with spring-loaded screws and locking nuts. Collimation of the instrument is very important, so I devised the following method for doing this. The technique is simple and accurate, provided the aluminized spot is centered perfectly on the corrector.

First, the corrector is removed and a piece of clear plastic, having its center well marked, is inserted. An 8″ length of tubing, $1\frac{1}{4}''$ in outside diameter, is put in place of the eyepiece. This tube has crosshairs at one end and a centered peephole in the other; the hole is made with a No. 50 drill, which is 0.07″ in diameter. By looking through the peephole, the crosshairs are aligned with the center of the plastic disk at the far end of the tube.

The flat in the diagonal housing is then adjusted until the crosshairs stay centered on the plastic disk for any position of the housing. The adjustment is quite easy if the flat is mounted on a piece of sheet brass held in the housing by three spring-loaded screws.

Then the plastic is replaced by the corrector. The tube is removed from the eyepiece holder and a plug with a small hole in its center is inserted in its place. The worker looks through the system at the daytime sky, and the reflection of the corrector's aluminized spot can be readily seen, unless, of course, it is already centered over the spot itself and no adjustment is necessary.

The finished instrument is superb, performing so well that my 12-inch Newtonian will probably get dusty from disuse.

GORDON KONSTANZER
2735 Milan Court
Los Angeles 41, Calif.

MOST amateur telescope makers' first mirrors have diameters of 6" and focal lengths near 48". To change such a mirror from a sphere to a perfect paraboloid involves removing approximately 0.000012" of glass from the center of the disk. The time needed to figure a mirror like this under ideal conditions can run from half an hour to two hours for the experienced ATM or carefully tutored beginner.

However, anyone who has made a 6-inch telescope with a short focal length, between 24" and 30", knows that it takes a lot of work to deepen the sphere to the desired paraboloid. Recently, a fairly experienced amateur who was working on a 12-inch mirror of 60" focus remarked he was happy that only a few millionths of an inch of glass would have to be removed to obtain the final figure. He was quite surprised when shown that the difference was very nearly 0.0001" in the center of the glass for the full correction.

The exact formula for the sagitta, **S**, of a sphere is

$$\mathbf{S} = \mathbf{R} - (\mathbf{R}^2 - \mathbf{r}^2)^{\frac{1}{2}}, \qquad (1)$$

where **R** is the radius of curvature of the mirror and **r** is the radius of the glass (its semidiameter). This formula is illustrated on page 187 of the February, 1957, issue. The approximate expression in telescope making books,

$$\mathbf{S} = \mathbf{r}^2/2\mathbf{R}, \qquad (2)$$

is not the sagitta of a sphere, but actually that of a paraboloid!

It is also common practice to expand the term $(\mathbf{R}^2 - \mathbf{r}^2)^{\frac{1}{2}}$ by the binomial theorem, to give:

$$(\mathbf{R}^2 - \mathbf{r}^2)^{\frac{1}{2}} = \mathbf{R} - \mathbf{r}^2/2\mathbf{R} - \mathbf{r}^4/8\mathbf{R}^3 - \mathbf{r}^6/16\mathbf{R}^5 - 5\mathbf{r}^8/128\mathbf{R}^7 \ldots \qquad (3)$$

In the past, only the terms through the $\mathbf{r}^6/16\mathbf{R}^5$ expression have been published in telescope making articles, and one would think the expansion simpler than it really is. Most telescope making literature uses the third term, $\mathbf{r}^4/8\mathbf{R}^3$, in one form or another, as a close approximation for the difference between a sphere and a paraboloid.

To find the exact difference between a sphere and a paraboloid, the sagitta of the sphere should be obtained in equation (1), that for the paraboloid from equation (2), and the difference between the two found. This has been done in Tables I, II, and III, the first giving the depth of a sphere, the second that of a paraboloid, and the third the difference between them.

It will be noticed that the paraboloid is shallower than the sphere, and this is contrary to the usual idea of deepening the sphere to obtain the paraboloid. In the table the two are tangent at the center of the mirror; if we move the paraboloid down by the amount of the difference, the two are tangent at the edges, the situation generally pictured.

Examination of Table III shows that the amount to be removed at the center of a 6-inch f/8 mirror in parabolizing it is 0.000012". At f/10 it is only half this amount, and at f/15 the mirror may be left spherical, as the difference is less than 0.000001" (one millionth of an inch). For a 6-inch f/4 mirror the central difference is 92 millionths.

However, in figuring a mirror we are actually removing stock from an area. Considering the two surfaces tangent at the edges, the amount of stock removed in a 6-inch f/8 varies from 12 millionths at the center to zero at the edges. What,

Aperture (inches)	f/4	f/5	f/6	f/7	f/8	f/10	f/12	f/15
				TABLE I: SPHERE				
6	0.093842	0.075047	0.062529	0.053589	0.046887	0.037506	0.031251	0.025000
8	0.125122	0.100069	0.083370	0.071452	0.062515	0.050008	0.041671	0.033336
10	0.156403	0.125078	0.104212	0.089314	0.078144	0.062510	0.052089	0.041670
12	0.187689	0.150094	0.125054	0.107177	0.093773	0.075012	0.062507	0.050004
16	0.250254	0.200125	0.166739	0.142903	0.125031	0.100016	0.083342	0.066671
				TABLE II: PARABOLOID				
6	0.093750	0.075000	0.062500	0.053571	0.046875	0.037500	0.031250	0.025000
8	0.125000	0.100000	0.083333	0.071429	0.062500	0.050000	0.041667	0.033333
10	0.156250	0.125000	0.104167	0.089286	0.078125	0.062500	0.052083	0.041667
12	0.187500	0.150000	0.125000	0.107143	0.093750	0.075000	0.062500	0.050000
16	0.250000	0.200000	0.166667	0.142859	0.125000	0.100000	0.083333	0.066667
				TABLE III: DIFFERENCE BETWEEN TABLES I AND II				
6	0.000092	0.000047	0.000029	0.000018	0.000012	0.000006	0.000001	0.000000
8	0.000122	0.000069	0.000037	0.000023	0.000015	0.000008	0.000004	0.000003
10	0.000153	0.000078	0.000045	0.000028	0.000019	0.000010	0.000006	0.000003
12	0.000189	0.000094	0.000054	0.000034	0.000023	0.000012	0.000007	0.000004
16	0.000245	0.000125	0.000072	0.000044	0.000031	0.000016	0.000009	0.000004
				TABLE IV: TOTAL STOCK REMOVAL IN CUBIC INCHES				
6	0.000433	0.000221	0.000128	0.000081	0.000054	0.000028	0.000016	0.000008
8	0.001026	0.000525	0.000303	0.000191	0.000128	0.000065	0.000037	0.000019
10	0.002003	0.001025	0.000593	0.000373	0.000250	0.000129	0.000074	0.000038
12	0.003462	0.001735	0.001024	0.000645	0.000432	0.000221	0.000128	0.000065
16	0.008206	0.004197	0.002427	0.001528	0.001023	0.000524	0.000303	0.000155

then, is the total amount of material removed from a mirror in parabolizing?

To find this, we need the equations for the volumes of a spherical and a paraboloidal segment. The following formulas can be used:

Volume of a spherical segment = $\pi S(r^2/2 + S^2/6)$

Volume of a paraboloidal segment = $\pi r^2 S/2$.

The difference between them gives $\pi S^3/6$, or $0.5236S^3$ for the volume of stock removed, and Table IV contains the values for the same mirrors as are listed in the other tables.

Thus, for the 6-inch f/8, 54 millionths of a cubic inch of glass (0.000054) must be removed. But for the same sized mirror at f/4, the total is 433. It is this extra stock (eight times as much) that makes it take so long to parabolize short-focus reflectors. Comparing the 6-inch f/8 with the 12-inch f/5 gives a good idea of the work needed to produce such a large surface (the 1,735 millionths of a cubic inch for the larger mirror is 32 times that for the smaller).

It is now clear why big instruments take so much longer to figure, and why it is necessary to increase polishing action by using subdiameter laps or special techniques. Professional opticians often begin parabolizing in the final stages of fine grinding, but this requires extremely good judgment of when to stop. Otherwise, the result will be a hyperboloid, which is even more difficult to correct than a sphere.

A good solution was proposed by E. L. Mason in Maksutov Club *Circular* 9: Semipolish the mirror on a hard lap, using very fine abrasives instead of rouge or Barnesite. A large part of the figuring can be achieved in this way, the polish obtained allowing Foucault testing. The final polishing and parabolizing are done with a regular or subdiameter lap and polishing compound.

This method is actually an old one, dating back to the 1930's, when kits did not contain the fine abrasives of today, but included as the finishing material either No. 400 or 600 grit having a micron size of 22 or 16. Modern finishing powders are a third to a quarter this size.

ALLAN MACKINTOSH
97 McLoughlin St.
Glen Cove, N. Y.

EDITOR'S NOTE: This article has been adapted in part from Maksutov Club *Circular* 62.

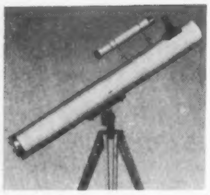
CORRECTION

The photograph of the Double Cluster in Perseus, page 332 of the April issue, is incorrectly described there. North is up, not south; the cluster to the left is Chi Persei, with h Persei to the right. This was pointed out by W. H. Sell, Platte City, Missouri.

"GLEANINGS" INDEX

A subject index to articles of lasting interest that have been published in this department during the past 18 years has been compiled by Allan Mackintosh and published as Maksutov Club *Circular* 64. The index covers Vols. I through XVIII of SKY AND TELESCOPE, but the names of authors are not listed. Also omitted are pure descriptions of observatories and of telescopes unless over 16 inches in aperture, but many subject references include smaller instruments.

Nonmembers of the Maksutov Club may secure a copy of the nine-page index by sending 25 cents to Mr. Mackintosh at 97 McLoughlin St., Glen Cove, N. Y.



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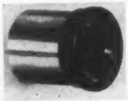

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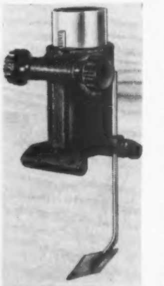

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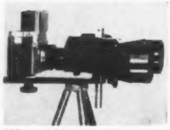

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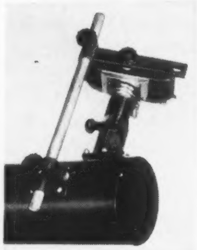

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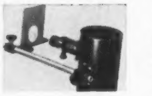

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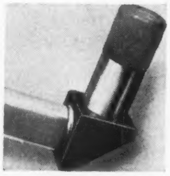

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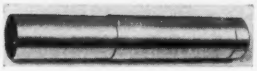

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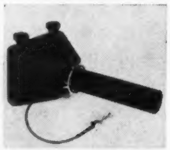

This model uses rolls of #127 film. Picture area will be a circle 1-9/16" in diameter.

The advantage of this model is the ease of using roll film. With each camera you get a piece of ground glass. Before loading film in the camera, you focus the telescope. Then lock it in this position. For positions other than infinity, you can scribe a mark on your tube.

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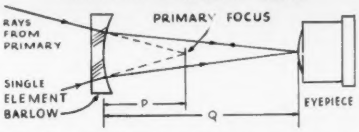

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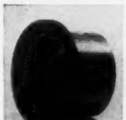

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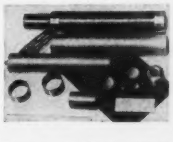

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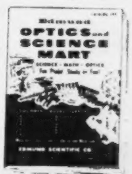

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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

Mercury in the Evening Sky This Month

GEMINI is the guide constellation to Mercury this June, for the planet will be within its boundaries most of the month. Greatest elongation will take place on June 19th, with the planet 25° east of the sun. At the beginning of the month, Mercury sets $1\frac{1}{4}$ hours after the sun, in midmonth $1\frac{3}{4}$ hours, and at month's end more than one hour.

Familiarity with the stars of Gemini, particularly Castor and Pollux, Gamma (Alhena), Delta, Epsilon, and Mu Geminorum, will help the observer in tracking Mercury through the month. For instance, on the evening of June 4th, it will be about 10° to the right (north) of Alhena, but much brighter than the star, for the planet's magnitude is then −0.3. It is to be very close to Mu, which may, however, be lost in the twilight glare.

By the 8th, Mercury will have moved eastward close to Epsilon Geminorum, the two making an interesting unequal pair in binoculars. At sunset, they are about as high above the horizon as Procyon, the 1st-magnitude star some 25° to the left of them in the sky. Mercury is also about 12° below Castor. The planet will form a long thin triangle with Castor and Pollux on the 12th, then being only about 3° east of Delta.

On the evening nearest elongation, the 18th, the planet will be passing some 5° south of Pollux, these two and Castor making a fine sight in the sky. The visual magnitudes then are Mercury +0.8, Pollux +1.2, and Castor +1.6. A line from Pollux toward Procyon will pass close to Mercury.

During the latter part of the month, the apparent motion of Mercury among the stars will be slower. By the end of June, it is almost in line with the twin stars. Mercury should still be easy to find if one has watched it from night to night, but it will have faded to magnitude +1.4, almost as faint as Castor.

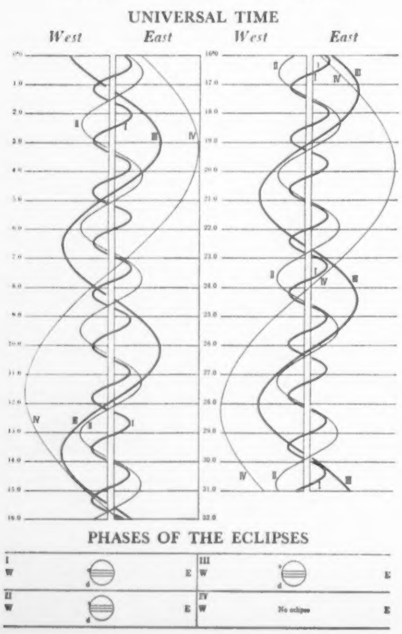
Telescopic observations will show marked changes in Mercury's appearance during June. On the first it is small and gibbous, about 80 per cent of its disk illuminated and only 5″.7 in diameter. By the 10th, with the disk somewhat larger, the phase resembles that of the first-quarter moon. At elongation, Mercury will be a broad crescent 8″ in diameter, and by month's end the disk will be only 20-per-cent illuminated and 10″ across.

JUPITER'S SATELLITES

The curves in the accompanying chart show the positions of Jupiter's four bright moons, as seen in an inverting telescope, with north at the bottom and east at the right. Each horizontal line is for 0^h Universal time on the date specified, and the intersections of the line with the curves indicate the places of the satellites at that time. For other Universal times, interpolate between the 0^h lines. The double vertical lines represent the planet's disk.

The lower section is intended to aid observations of the eclipses of Jupiter's moons; *d* is the point of disappearance of the satellite in Jupiter's shadow, *r* is the point of reappearance. The chart is from *The American Ephemeris and Nautical Almanac;* for further explanation, see page 446 of SKY AND TELESCOPE for May, 1960.

JUPITER'S SATELLITES IN JUNE

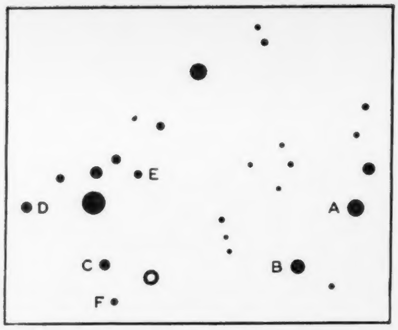


SZ HERCULIS

USERS of 6-inch telescopes or larger can spend an interesting June evening watching the striking brightness changes of SZ Herculis. It is an Algol-type variable with the short period of 19 hours 38 minutes. Normally near magnitude 10.2, it fades to about 11.9 in only 2.2 hours, and regains its former brightness in an equal interval. Thus, the light changes are exceptionally rapid and easy to observe.

The 1950 position of SZ Herculis is 17^h $37^m.8$, +32° 58′, roughly midway between Vega and Delta Herculis. Observers who do not use setting circles should first pick up the $6\frac{1}{2}$-magnitude star shown in the Skalnate Pleso atlas at 17^h $37^m.0$, +32° 46′; this is the brightest object plotted in the accompanying field chart.

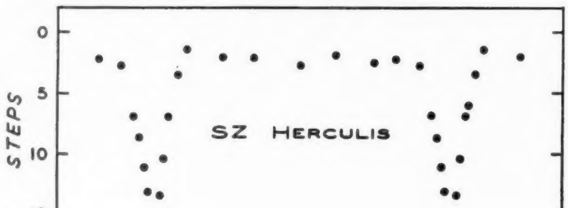
Approximate Universal times, to the nearest 0.1 hour, of the midpoints of eclipses convenient for observation in North America are: June 1, $2^h.6$; 5, $4^h.8$; 14, $4^h.8$; 18, $7^h.0$; 19, $2^h.6$; 23, $4^h.8$; 27, $7^h.0$; 28, $2^h.6$. Predictions of other minima can be obtained by adding multiples of 19.63 hours to these times.



SZ Herculis is indicated by a small circle in this finder chart, which is one degree wide, with south on top. The brightest star is of magnitude $6\frac{1}{2}$. Approximate visual magnitudes of labeled comparison stars are: A, 9.8; B, 10.2; C, 10.4; D, 10.9; E, 11.4; F, 11.9.

The period of SZ Herculis is changing; hence new determinations of the times of its minima are highly desirable. Readers with some experience in observing variable stars are invited to co-operate in this. The magnitude of the variable is to be estimated every quarter hour or so, beginning $1\frac{1}{2}$ or two hours before the predicted time of minimum, and continuing that long after it. The time of each estimate should be recorded to the nearest minute.

All relevant details should be given with any such series of observations sent in to SKY AND TELESCOPE for analysis. Observers who wish to derive times of minima from their own estimates will find a simple but precise graphical procedure explained in the February, 1957, issue, page 190.



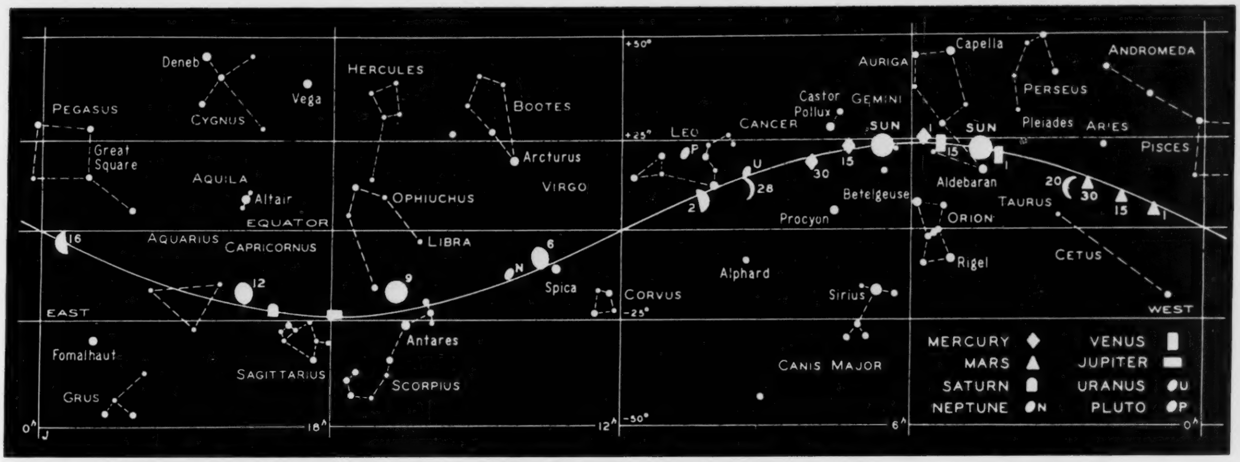
This light curve of the Algol-type variable SZ Herculis was derived by Miss A. A. Vasilieva from 214 visual estimates with the 6-inch refractor of Stalinabad Observatory. The vertical scale is brightness, expressed in arbitrary steps. Adapted from the Soviet journal, "Variable Stars."

MINIMA OF ALGOL

June 2, 18:36; 5, 15:25; 8, 12:14; 11, 9:03; 14, 5:51; 17, 2:40; 19, 23:29; 22, 20:18; 25, 17:06; 28, 13:55.

July 1, 10:44; 4, 7:32; 7, 4:21.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury reaches greatest eastern elongation on June 19th, when it will be 25° from the sun, setting about $1\frac{3}{4}$ hours after it. This is a favorable elongation for Northern Hemisphere observers, and Mercury should be fairly easy to find all month, as explained in the discussion on the facing page. The thin crescent moon will be near Mercury on the evening of June 25th.

Venus comes to superior conjunction on June 22nd, and will be too near the sun all month to be observed.

Earth reaches heliocentric longitude 270° on June 21st, at 9:43 Universal time. This marks the solstice, summer beginning in the Northern Hemisphere, winter in the Southern.

Mars rises about three hours before the sun in midmonth, and is a 1st-magnitude object in Pisces. Telescopically, the planet's disk is slightly gibbous – 89-percent illuminated – and only 5″.8 in diameter. Mars is too distant for satisfactory observations of its surface detail. The moon will be near the red planet on the morning of June 18th.

Jupiter reaches opposition to the sun on June 20th, 394 million miles from the earth. It then rises about sunset and is prominent in the southern sky (in Sagittarius) all night. Its magnitude is –2.2, and a telescope will show its oblate disk, 46″.5 in equatorial diameter and 43″.4 in polar. The moon will be near Jupiter the night of June 9-10, being 5° north of the planet at 7^h UT on the 10th. That same night, the giant planet will be located in front of the Trifid nebula, M20.

Saturn is in Sagittarius, being about 20° east of Jupiter on the 15th, and rising then about $1\frac{1}{2}$ hours after sunset. The magnitude of the planet is +0.4. Even a small telescope will show Saturn's rings, 41″.2 in extent and having their northern face tipped 24° to our line of sight this month. The planet's polar diameter is 16″.4. The moon will pass near Saturn on the night of June 10-11, with conjunction at 10^h UT on the 11th, the moon being 4° north.

Uranus is a 6th-magnitude object near the Leo-Cancer boundary in June, as shown in the finder chart on page 191 of the January issue. It may be seen in the western sky during the early evening, setting about three hours after the sun.

Neptune is near the Virgo-Libra border, and may be found with small telescopes and the chart on page 191 of January. This 8th-magnitude object crosses the meridian about an hour after sundown, and is in the southwestern sky later in the evening. The planet's tiny greenish disk is 2″.5 in diameter.

W. H. G.

MINOR PLANET PREDICTIONS

Vesta, 4, is of the 6th magnitude this month. The finding chart and extended ephemeris, printed on page 447 last month, can be used for observing it in June.

Pallas, 2, 9.4. June 15, 19:20.0 +21-57; 25, 19:12.7 +22-11. July 5, 19:04.6 +21-57; 15, 18:56.3 +21-15; 25, 18:48.7 +20-07. August 4, 18:42.3 +18-38. Opposition on July 6.

Bamberga, 324, 9.8. June 25, 20:24.4 –31-59. July 5, 20:16.8 –32-08; 15, 20:06.4 –32-06; 25, 19:54.7 –31-47. August 4, 19:43.1 –31-06; 14, 19:33.4 –30-08. Opposition on July 20.

Melpomene, 18, 8.9. June 25, 20:29.1 –7-45. July 5, 20:24.1 –8-16; 15, 20:16.6 –9-12; 25, 20:07.5 –10-30. August 4, 19:58.1 –12-03; 14, 19:49.9 –13-44. Opposition on July 23.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VARIABLE STAR MAXIMA

June 3, R Virginis, 123307, 6.9; 4, S Herculis, 164715, 7.6; 5, RU Sagittarii, 195**142**, 7.2; 9, T Centauri, 133**633**, 5.5; 10, RS Librae, 151**822**, 7.5; 17, T Aquarii, 204**405**, 7.7; 18, R Octantis, 055**686**, 7.9; 29, R Aquilae, 190108, 6.1.

July 2, RR Sagittarii, 194**929**, 6.8; 9, SS Virginis, 122001, 6.8.

These predictions of variable star maxima are by the AAVSO. Only stars are included brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

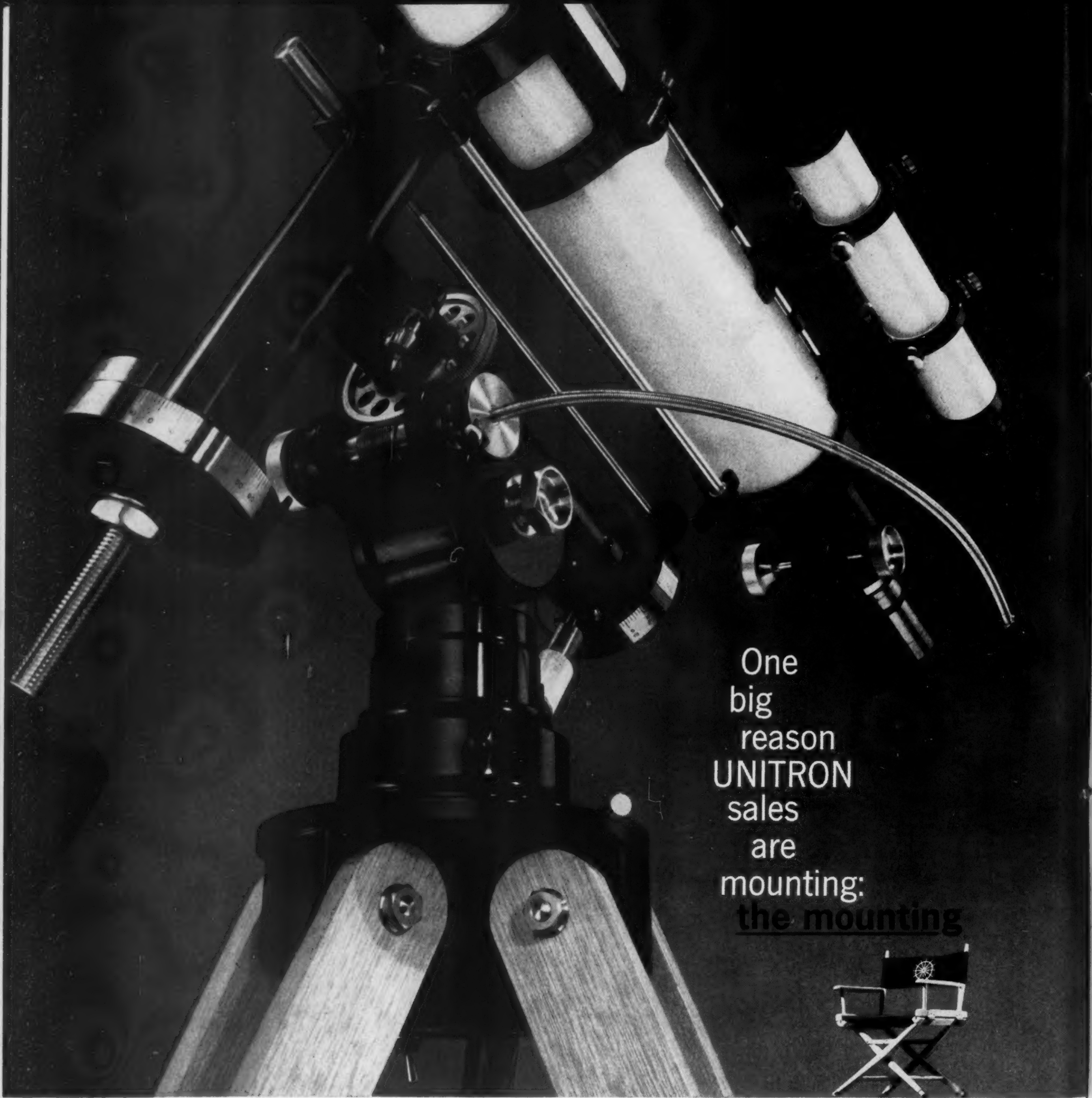
MOON PHASES AND DISTANCE

First quarter	June 2, 16:02
Full moon	June 9, 13:02
Last quarter	June 16, 4:36
New moon	June 24, 3:27
First quarter	July 2, 3:49

June	Distance	Diameter
Perigee 10, 2^h	222,100 mi.	33′ 26″
Apogee 24, 10^h	252,700 mi.	29′ 23″
July		
Perigee 8, 11^h	221,900 mi.	33′ 27″

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.



Equatorial mounting of the 4″ UNITRON refractor, Model 152.

Step up, friend. Sit yourself down at the controls of a UNITRON. Feel the sure response of the slow-motion controls. Note the extra-smooth handling ease. Observe the oversize components, which give UNITRON mountings strength to spare.

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Note, too, the precise slow-motion adjustment for declination. Scrutinize the precision gears designed to deliver generations of velvet-smooth performance. Examine the large easy-reading setting circles and verniers provided on the 3″ and larger models.

(What you won't see is the instrument's complex of inner workings — a blend of the arts of the artillery engineer and the Swiss watchmaker that gives you an instrument whose response will be obedient to the slightest touch of your fingers.)

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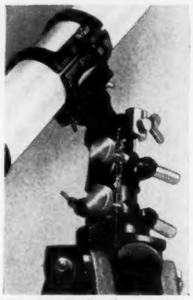

Sturdy altazimuth mounting with slow-motion controls as well as rapid motions for altitude and azimuth.

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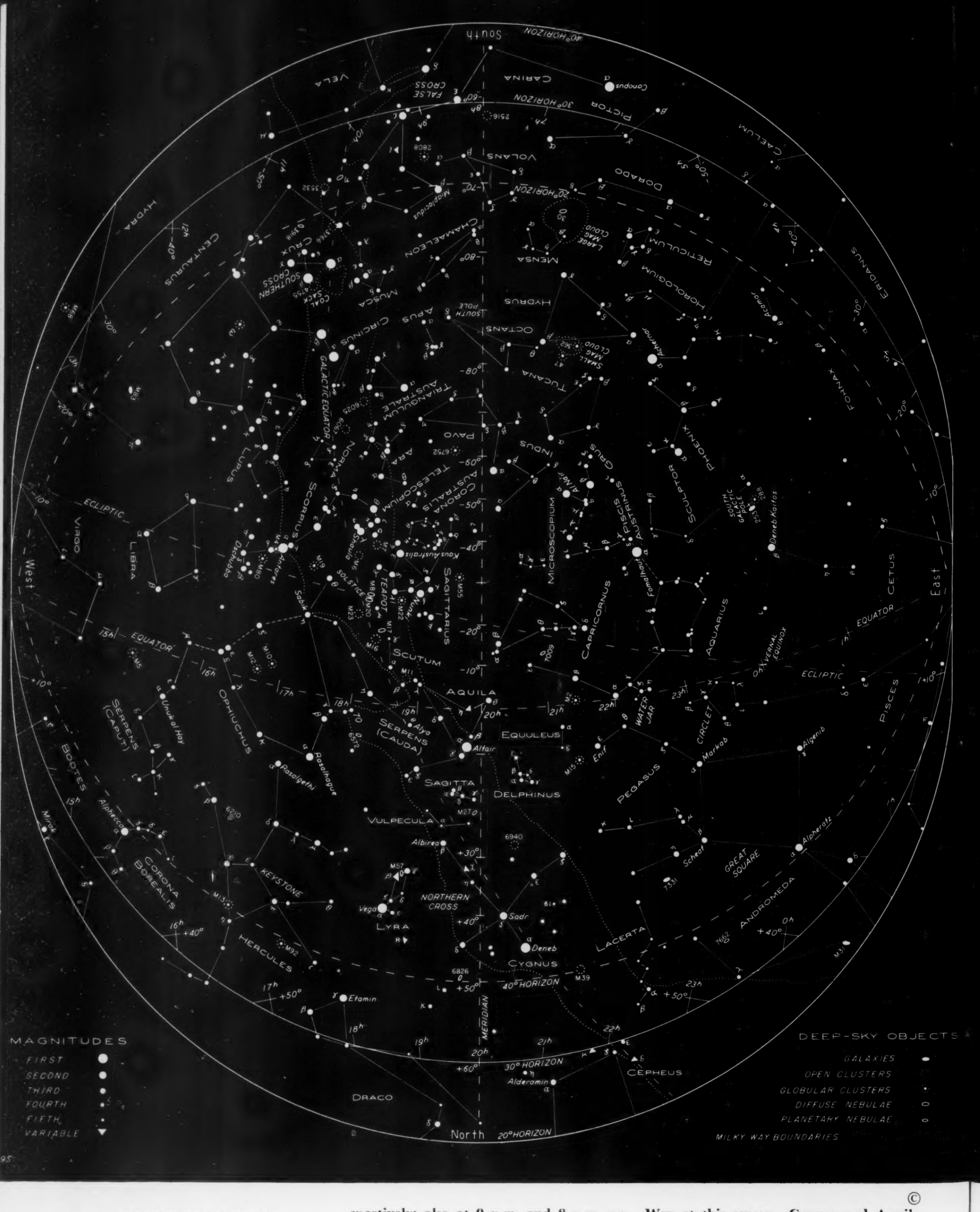

SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 6th and 22nd of August, respectively; also at 9 p.m. and 8 p.m. on September 6th and 21st. For other dates, add or subtract ½ hour per week.

Observers south of the equator have their best views of the northern Milky Way at this season. Cygnus and Aquila are the most prominent constellations in this area of the sky, but the small groups Equuleus, Delphinus, Sagitta, and Vulpecula should not be overlooked.

©

STARS FOR JUNE

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of June, respectively. For other dates, add or subtract ½ hour per week.

In the east at chart time are the familiar constellations of summer, while those of spring are descending in the west. Bootes the Herdsman is nearly overhead, with Arcturus prominent. Spica is now well placed in the south. Look low in the southeast for the red 1st-magnitude star Antares, in Scorpius.

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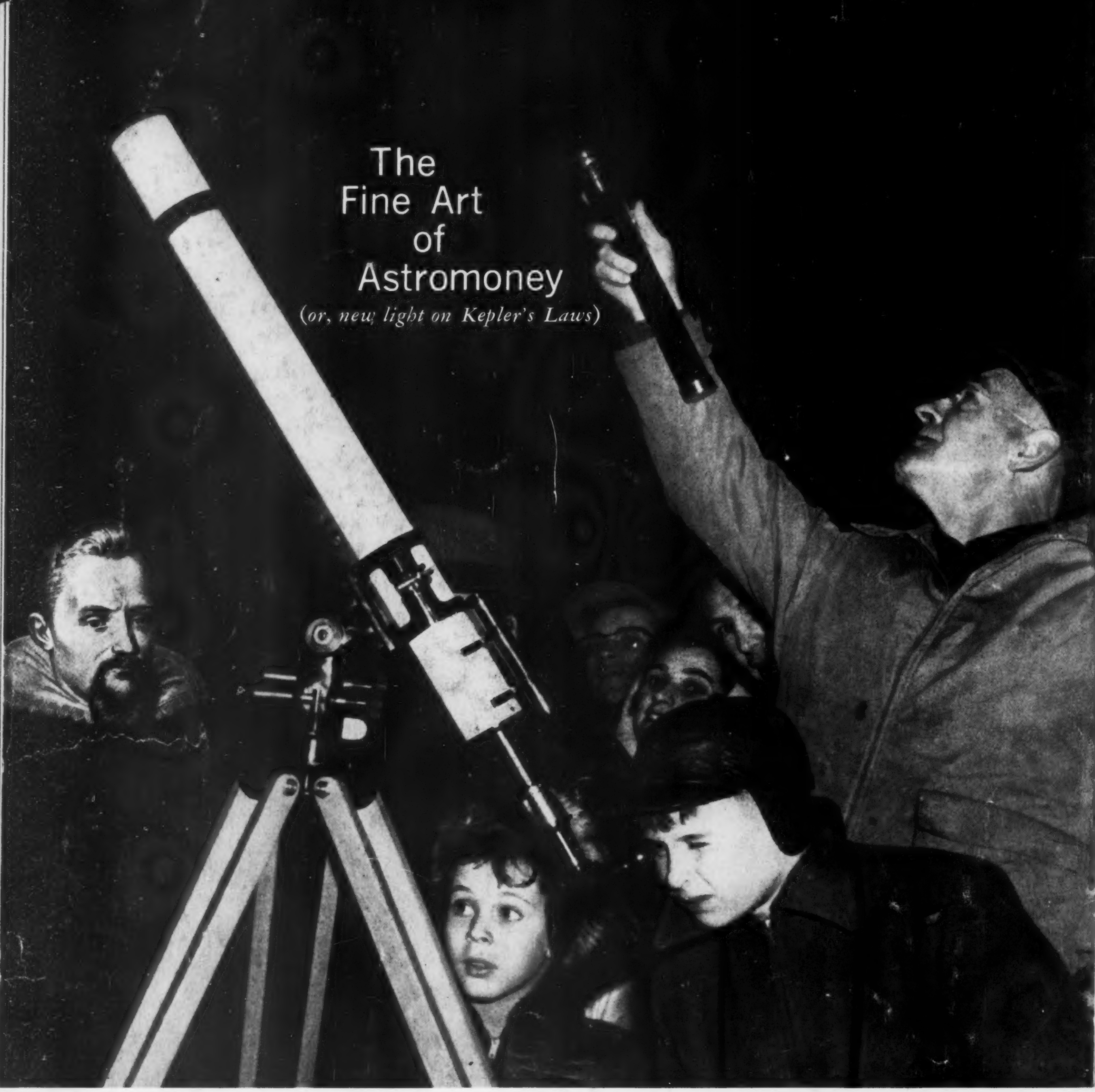

It is with no Disrespect toward the mighty Johannes Kepler that we humbly suggest he overlooked Something.

We have no Quarrel with his Three Laws Unraveling the Mysteries of Celestial Motion. But what of Earthly Economics? What profits us to know about the Elliptical Orbits of Planets if we have not the Wherewithal to pursue them with Pleasure? Astronomy is all well and good — but what about Astromoney?

Astromoney is precisely what Kepler Forgot . . . the Fine Art of getting the most Pleasure out of Astronomy for the least Money. Its Laws, like Kepler's, are three in number:

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Second Law: when you consider Value, consider UNITRON first.

Third Law: when you consider UNITRON, you have it made.

There may be those who will Doubt. They may say the UNITRON of their Choice, although attractively priced, is too Taxing for their Budget. Torn by the Conflict between Desire and Stern Economic Reality, they may abandon the pursuit of Pleasure altogether.

For such as these, there is a fourth Law of Astromoney:

"If you would enjoy your UNITRON, and Keep the Wolf at bay —
Send just one tenth its Price — and take a Year to pay."

The wisdom contained in the fourth Law is summarized in the adjacent Table. It is as Valuable for the Reader as the Rudolphine Tables were for the contemporaries of Kepler.

Pursuing pleasure in the picture above are a few of the many interesting visitors who participate in the "Star Gazers" meetings offered by the Long Island State Park Commission in association with Abraham and Straus. Mr. Percy Proctor, director, indicates the location of a planet while a youngster views it through a UNITRON 2.4" Altazimuth Refractor.

	Prices	Down Payment	Monthly Payment
1.6" Alt.	$ 75	$ 7.50	$ 5.96
2.4" Alt.	125	12.50	9.93
2.4" Eq.	225	22.50	17.88
3" Alt.	265	26.50	21.05
3" Eq.	435	43.50	34.58
3" Ph. Eq.	550	55.00	43.72
4" Alt.	465	46.50	36.96
4" Eq.	785	78.50	62.40
4" 160	1175	117.50	91.41
4" 166	1280	128.00	101.76

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SEE PAGES 510 AND 511 FOR MORE ABOUT UNITRON.

Sky and TELESCOPE

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